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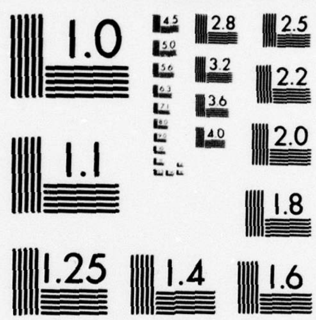


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# AH-64 FLIGHT AND WEAPONS SIMULATOR CONCEPT FORMULATION STUDY

VOLUME 2 OF 2

CAE ELECTRONICS LTD.

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5 October 1977



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The results of a feasibility study for the design of an Advanced Attack Helicopter Flight and Weapons Simulator are reported. Desirable trainer functions have been analyzed resulting in Trainer performance requirements. A comparison of available and developmental techniques using performance and cost criteria for selection has resulted in a recommended configuration for the simulator.

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## SECTION 7

## INSTRUCTOR/OPERATOR CONTROLS

## 7.1 INTRODUCTION

An analysis of the instructor/operator controls required and a recommended instructor/operator facility to meet the needs of the AH-64 FWS are discussed in this section.

In a mission trainer such as the FWS, the trainees interact with a complex scenario involving threat array, atmospheric conditions, communications to friendly forces, etc., and their performance is monitored to ascertain the resulting skill levels. The management of this training environment and subsequent performance monitoring form the basis of instructor/operator control design.

The effect of the FWS configuration on the ability to monitor trainee performance and the necessity for instructor presence were the first subjects of analysis. This phase progressed to an analysis of facilities necessary to give the instructor the ability to control the environment efficiently and to allow effective monitoring of trainee performance. Subsequent analysis of hardware modules produced the basis for the recommended AH-64 FWS instructor/operator facilities discussed in paragraph7.4.

## 7.2 INSTRUCTOR FACILITIES FEATURE ANALYSIS

### 7.2.1 Approach to Instructor's Facility Design

7.2.1.1 Instructor Task Density. Instructors or operators on the AH-64 FWS will be required to control the training environment for trainees and monitor their performance. Such tasks as threat manipulation, malfunction insertion, position monitoring, communications management and mission initialization are required as well as an evaluation of trainee progress on which an instructor can recommend an improvement in technique. The task density on an instructor is related to the amount of supervision needed by a trainee. In the initial stages of training, such as in AH-64 transitioning, the amount of supervision is liable to be high. When trainees are being AH-64 mission trained in engaging threat forces, we believe they will have already passed through the transition stage and the supervision will be directed towards the team rather than the individual.

Both situations must be covered in the design of the instructor's facility as we believe that the AH-64 will be used for both types of training: transitional training at Fort Rucker and mission training at unit level. The use of automated features is clearly indicated to cope with the overall task density, and by varying the complexity of the automated features, we can effectively vary the number of instructors needed.

Three approaches to instruction with automated features were considered.

7.2.1.2 Full Automation Instruction. The fully automated approach would provide fully automated training mission management and performance evaluation packages that can be controlled by one or more simulator operators from a centralized operator's console. Automated demonstration of tactical maneuvers would also be included.

. Advantages

. Minimum personnel costs

. Maximum training standardization

. Disadvantages

. Increased software costs

. Reduced training transfer due to loss of flexibility in presentation

. Difficulty in producing a comprehensive and accurate performance evaluation package

Clearly the disadvantages outweigh the advantages, and a mixture of instructor and automation should be considered.

7.2.1.3 Full Automation with Instructor Performance Assessment. This system would include the same facilities as the approach discussed in paragraph 7.2.1.2, plus an instructor monitoring the student's progress. The automated features would still be controlled by simulator operators.

. Advantages

. Probable cost advantage in trade-off of instructors versus more complex software

. Use of an instructor/pilot would avoid some high risk development areas in performance evaluation and software

. High level of trainee confidence through presence of instructor; e.g., instructor overrules or qualifies performance assessment.

. Assistance to trainees can be more effective when tailored by an instructor.

. Exposure to simulator will assist in standardization of training provided by instructors

- A better integrated training system, in which each instructor sees the simulator as another training tool with its own particular advantages over the use of the real aircraft.

7.2.1.4 Automated Features Under Instructor Control. This approach is similar to that described in paragraph 7.2.1.3, except that the instructor has full control over the training mission. The training mission management would be in lesson plan form, allowing the instructor to proceed with the mission at a rate dependent on the ability of the trainee.

- Advantages are the same as described in paragraph 7.2.1.3, plus:

  - Elimination of the need for a simulator operator, since preprogrammed lesson plans will simplify operator functions.

  - Training supervisors will have maximum assurance that trainees are receiving training in the selected areas.

7.2.1.5 Recommended Method of Instruction. After review of the alternatives available and the AAH mission, the most suitable combination is believed to be as follows:

- Employment of automated maneuver demonstration and performance evaluation in selected areas. (An estimated 50% of the requirement can be handled with adequate validity.)

- Utilization of an instructor or instructors with primary responsibility the same as that for airborne instruction (i.e., demonstration and assessment) for those exercises and functions that cannot be readily automated.

- Utilization of preprogrammed lesson plans to minimize operator-type functions.

This approach would permit manning of the simulator for most exercises by one instructor who would manage the overall mission. In some cases, particularly at the aviation school level, two instructors would be desired to enable direct viewing of each trainee. Mission management by one instructor would normally be conducted from the pilot trainee compartment. Video repeat of the copilot/gunner TADS and TV displays would be required to ensure adequate awareness of CPG actions. Successful implementation of proposed aids to the instructor and scenario management techniques would eliminate the need for simulator operators.

Checkout time for instructors would be targeted at four hours on the simulator.

### 7.2.2 Instructor Station Layout

7.2.2.1 Instructor Station Position. The simulator configuration of separate pilot and CPU flight compartments and mounted on separate motion bases allows two instructor station layouts.

(a) Instructor station onboard each flight compartment.

(b) An external instructor station remote from the flight compartment.

We expect the FWS will train both inexperienced crews transitioning to the AH-64 and experienced pilots during mission training.

In the first case, that of transition training, we believe instructors should be able to directly monitor both crew members performance. U.S. Army training establishments favor direct monitoring of the trainees particularly when new skills are being introduced. This is to ensure that the correct techniques are being used in problem situations. The use of Independent Crew Training where the pilot and CPG may be trained in separate tasks may also be an area to be used in transitioning. The pilot could practice hovers and antirotations while the CPG is instructed in the use of TADS.

The initial use of the first FWS installation at Fort Rucker will be used mainly for transition training which strongly indicates a need for instructor stations behind each trainee.

We feel that a remote instructors station would not provide as effective instructional monitoring in the early stages of training and the use of an external station plus two observers on-board represents an increase in manpower although perhaps an initial saving in equipment cost.

For these reasons we recommend the installation of a pilot instructors station and a CPG instructors station behind the respective trainee positions.

7.2.2.2 Instructor Station Modules. When considering mission training it appears that the instructor will have to evaluate general parameters such as crew tactical decisions and reaction to threat rather than specifics such as hovering techniques. Use of two instructors placed as before would be preferable but considerable saving in manpower costs could result if this type of training could be handled by one instructor.

In this case the instructor station components would have to allow an instructor situated behind either trainee to have complete control over the situation and be able to monitor both crew members. By having two identical instructor stations, capable of complete mission control, one behind each trainee, it would be possible to have one instructor control a complete mission while directly monitoring the crew member of greatest interest.

In both transitional and mission training we recommend the use of a repeat visual monitor at each instructors station to reflect the images being presented on the TADS and PNVS. We feel these monitors could also be used when one instructor is supervising a crew mission training session. If he is positioned in the pilots flight compartment he could watch pilot actions directly and monitor the CPG's operation of TADS on the repeat monitor.

7.2.2.3 Recommended Instructors Station Layout. The instructor station layout recommended for the AH-64 FWS is as follows:

(a) Two instructors stations - one mounted in the pilot's flight compartment and one mounted in the CPG flight compartment.

(b) A visual repeat monitor at both instructors station to relay the TADS on PNVS video.

(c) Both instructor stations to have the capability to allow crew mission training by one instructor.

7.2.3 Desirable Instructor Controls. By taking the recommendations of paragraphs 7.2.2.1 and 7.2.2.2 and analyzing the AAH training mission, it is possible to recommend features for inclusion in the AH-64 Instructor facilities.

7.2.3.1 Exercise Setup. The instructor/operator (I/OP) must be able to perform the following setup tasks quickly and with a minimum of distraction from his primary duties of trainee assessment and problem demonstration.

. Set aircraft configuration

. Set aircraft position

. Set environmental conditions

. Activate simulator systems (e.g., motion, visual)

To perform these tasks effectively, a combination of direct action switches and CRT page line control functions is recommended.

In addition, a prerecorded set of commonly used setups should be available for callup by the I/OP. These should include both on-ground and in-flight conditions.

7.2.3.2 Malfunction Management. The I/OP must have sufficient control over malfunctions to ensure that they are employed in the most effective and realistic manner. The detailed system simulation provided in modern CAE trainers ensures the availability of accurate malfunctions effects at a relatively small cost increment. The following malfunction handling features are recommended for the AH-64 FWS:

- Direct action insert capability for all malfunctions with minimum manual effort.
- Criteria activation capability for designated malfunction (e.g., engine fails on translation through 20 kt). Criteria are pre-inserted and the malfunction is armed by I/OP.
- Automatic activation. A malfunction will occur any time certain conditions are met (e.g., gearbox fails after 10 minutes of operation at engine torque in excess of 110%).
- Variable malfunction characteristics. The I/OP should have the capability to control the abnormality, e.g., nominal deviation, amplitude of fluctuations, frequency of fluctuations.

7.2.3.3 Communications Management. To provide realism and to ensure that task difficulty is representative of the real-world tactical situations the I/OP must be provided with the means to respond to all transmissions from the AH-64 crew and to provide a full complement of background communication exchange. In addition, the I/OP must be able to monitor pilot/CPG intercom, and a private interphone between I/OPS is required for inclusion in a two-cabin configuration. A combination of the following techniques is recommended for the AH-64 FWS:

- Direct response by the I/OP to pilot or CPG transmissions (e.g., pilot requests time check).
- I/OP activation of prerecorded randomly accessible messages (e.g., pilot requests weather sequence).
- Criteria-activated transmission to AH-64 crew (e.g., as the aircraft passes point A, a target handoff is provided by the scout).
- Background fill-in communications exchanges not directed at AH-64 crew are activated automatically by the program or manually by the I/OP. This type of communication also qualifies as a mechanism to increase the difficulty of the training task.

7.2.3.4 <u>Problem Demonstration</u>. It is a recognized approach to pilot training that the trainee be shown a maneuver or procedure prior to attempting it on his own. The I/OP must be provided with the capability to demonstrate maneuvers to the trainee in a precise and standardized manner. In addition, there is proven value in demonstrating variations or portions of a maneuver tailored to a specific trainee problem.

The following demonstration techniques are recommended for the AH-64 FWS:

- Automated Maneuver Demonstration. A library of prerecorded, digitally stored maneuvers available to the I/OP for presentation to trainees. The following features are desirable:
  - Capability of running only a portion of the selected maneuver, the start and end point to be determined by the I/OP.
  - Availability of a prerecorded synchronized commentary.
  - Slow-motion demonstration.
- Manual Maneuver Demonstration. Flown by an I/OP from one of the trainee stations. This technique is only valid when the I/OP is an Instructor/Pilot (I/P). It is probable that some portion of the training syllabus could be effectively scheduled for this approach, with the second trainee observing the exercise.

7.2.3.5 <u>Performance Assessment</u>. It is necessary that the I/OP be provided with the means to accurately assess trainee performance. The following techniques are recommended for the AH-64 FWS to enable ease of monitoring by the instructor:

- Direct assessment of trainee performance through I/OP monitoring of cockpit indicators, visual display, TADS and PNVS repeat, and trainee actions.
- Plotting of time histories of selected aircraft parameters (e.g., track on map, airspeed, altitude).
- Computer assisted recording of trainee action sequence and time interval (e.g., checklist and emergency procedure CRT pages).

- Computer analysis of performance (e.g., RMS or time on target scoring of parameters such as airspeed and heading).

- Computer scoring models developed specifically for attack helicopter role (e.g., AH-64 exposure(unmask) time or Hellfire missile delivery success).

It is believed that the greatest success in performance assessment can be achieved through the use of aircraft qualified instructors in the FWS flight compartment. For most training situations the preprogrammed lesson plan, in which selection of assessment techriques is performed in advance, is recommended to avoid the need for hasty decisions during the exercise.

7.2.3.6 <u>Trainee Feedback</u>. To achieve high transfer of training, it is essential that the trainee be made aware of and understand any shortcomings in his completed training tasks. It is important that feedback be provided soon after the task is attempted; in some cases, immediate review is possible and in others it can only occur during postflight debriefing. The following features are desirable to assist the I/OP in providing good feedback to the trainees in the AH-64 FWS :

- Record and Playback. This system would preferably run full time, and the I/OP would designate specific segments for later use.

- Map and Tactical Scenario Plotting (with hardcopy). The I/OP initiates hardcopy of those plots considered useful for debrief.

- Store Recall. The I/OP stores pertinent static cases (snapshots) of the training situation.

- Parameter Plotting with hardcopy (e.g., altitude during contour flight).

For efficient use of the above features, it is desirable that the I/OP be familiar with all training objectives to the extent required of an instructor/pilot.

7.2.3.7 <u>Scenario Management</u>. The deployment of vehicles and personnel in a combat scenario can follow a multitude of routes. In addition, objectives will change as the battle develops. It is therefore important that a means be provided to alter the tasks confronting the AH-64 crew in a realistic manner. Control over at least the following elements of the scenario is required:

. Number and type of vehicles

. Position, heading, and speed of each vehicle

. Status of vehicle weapons system

. Restrictions to visibility: smoke, haze, camouflage

Control of the scenario would be exercised by using the following techniques:

. Manual Mode. I/OP enters changes to the above parameters in accordance with a predetermined battle plan.

. Automatic Mode. Scenario changes automatically as the mission progresses. Changes can occur as a function of time or response can be geared to interactive considerations such as destruction of a specific target.

The second approach is recommended as the primary mode to be employed on the AH-64 FWS. Manual control of a battlefield situation would create an instructor workload in excess of that which could be managed by one I/OP.

It is not foreseen that alteration of threat characteristics such as time to fire or rate of fire would be desirable during an AH-64 mission.

7.2.4 <u>Independent Crew Training</u>. A feature not previously discussed in the instructor facilities feature analysis is the possibility of independent crew training in a simulator configuration with separate cabins for the pilot and CPG.

Three alternative approaches have been considered to implement this feature should it be desirable for the AH-64.

(a) Each trainee station can be set up in a static condition with all systems operational. Static setups include in-flight conditions. The instructor has simple controls for setting static flight conditions.

. <u>Advantage</u>

. Minimum cost approach.

. <u>Disadvantage</u>

. No training value for dynamic flight situations.

(b) Each trainee station has full mission capability. The instructor fulfills the role of the other crew member, using autopilot type controller.

. Advantage

. Approaches full mission capability for each trainee (limited only by possible constraints on visual viewing area and compromises in aircraft controllability from other than fully simulated cockpit).

. Disadvantage

. High cost

(c) Prerecorded exercises are used to provide the 'other crew member' input. Static setups as in alternative (a) are included.

. Advantage

. Provides limited dynamic capability at moderate cost.

. Disadvantage

. Trainee is not fully interactive with the mission.

The requirement for and capability of this feature, should it be proven essential, can be determined only when the extent of utilization is better defined.

A best guess at this time suggests minimal utilization (less than 10% of total simulation time), primarily because of the emphasis on combined crew training in the AAH role.

7.2.5 Adaptive Training. Considerable experience has been gained in the application of adaptive training in instrument flight trainers. It is well established that the success of this approach is inversely related to the complexity of the flying task; for example, straight and level instrument flight composed of tracking tasks which remain unchanged throughout the exercise can be effectively handled in an adaptive system. The logic for adjustment of task difficulty is simple and reliable and the change in difficulty can be introduced immediately an appreciable change in performance is detected. In addition, all elements of straight and level flight can be readily specified in terms of target values and acceptable deviations(tolerances).

The fundamental elements of adaptive training are:

- Valid and reliable performance measures.
- One or more system, task, or environmental variables that directly affect task difficulty.
- A logic which automatically adjusts task difficulty on the basis of measured performance.

It is worth noting that all three of these elements are essential, but that only the automatic aspect of the third is unique to adaptive training. In the AH-64 FWS, where the emphasis will be on complex maneuvers such as NOE navigation, avoidance of exposure to enemy fire and the effective use of weapons systems, several areas of doubt with regard to the successful automation of task difficulty variation are raised.

With reference to the first element of adaptive training, there is reason to doubt that all parameters applicable to these training objectives can be completely assessed using computer scoring techniques; for example, a scoring model which has sufficient branching capability to score the trainee's choice of routing when faced with an unexpected hazard during NOE navigation is probably not practicable because of the number of correct alternatives available. In this case, an instructor/pilot or equivalent is required to provide a subjective assessment to assist in arriving at the decision to modify the task difficulty. The one aspect of adaptive training for which the AAH problem offers encouragement is the availability of adaptive variables. Since an interactive threat force is envisaged, all of the many variable characteristics of such a force in terms of content and tactics qualify as adaptive variables.

If one assumes that an adaptive system which includes subjective assessment is not practical for the AH-64 FWS, we are left with the probability that only a few part task training objectives qualify for adaptive treatment, such as, for example, rocket firing, where the speed, detectability or range of the target are automatically altered as a function of hit/miss ratio.

In conclusion, the development of a totally adaptive training system for the AH-64 FWS is judged as impractical for lack of adequate automated scoring systems for full mission training. There appears to be justification for adaptive training as applied to part task objectives. It is envisaged that such training could be provided effectively in an independent crew mode with a simulator operator rather than with an instructor/pilot (I/P), or equivalent, managing the system.

## 7.3 INSTRUCTOR'S CRT DISPLAY SYSTEM ANALYSIS

7.3.1 General. The CRT display system can be an extremely flexible tool used by the instructor to monitor and control simulator status, and a system from which permanent records may be produced via a hardcopy device. The usefulness of the system depends on the ability of the instructor to interact efficiently with the simulator, efficiency being defined as minimum user effort yielding maximum displayed information or maximum control. The three determining factors affecting the organization of the display system are (1) what is to be displayed, (2) how it is to be displayed, and, consequently, (3) how many separate monitors are required.

The instructor should be able to monitor and/or control the simulated aircraft external and internal environments, all aircraft systems, and threat and friendly forces as anticipated in the real aircraft mission envelope. The instructor should also have the capability of displaying performance measurement aids, results, map plots, and time history plots, as well as other special formats, e.g., lesson plans, index pages, etc.

The display formats should use plain English, if at all possible, or unambiguous abbreviations. Numeric codes or three-letter abbreviations require the instructor to either memorize masses of information or constantly refer to decode manuals. The only excuse for coding information here would be to increase the number of parameters that can be presented in a given area. It will be shown later that all necessary data can be displayed without resorting to coding techniques. Cluttered formats should be avoided, and multiple CRT page accesses should be minimized by the careful organization of the data to be displayed.

The utilization of blink, levels of brightness, or different colors greatly aids in keeping a display uncluttered. All data should be represented in real-life units, and changing data should be updated at a reasonable rate. All of the above remarks are made keeping in mind their workload reducing effect on the instructor.

The next item for discussion is the number of monitors that can adequately handle the requirements just defined. Are one, two, or more separate monitors needed?

An analysis of the information requiring display during a typical training situation will give an indication of the number of monitors required. Assume that the system is in lesson plan mode, since this is the least demanding on the display system with respect to interaction. In any time span, the following may be of prime interest to the instructor:

. Present and next lesson step description

. A/C conditions, loading, wing stores status, etc.

. Communication frequencies tuned

. List of active malfunctions

. Map plot

. Time history plot

Display of all of the above items at once on a single monitor would result in an extremely crowded presentation. The instructor could, of course, switch from display page to display page, searching for, then remembering all the information conveyed to him by the formats. We believe this is a misuse of the instructor's time and ability, which should be reserved for coaching and monitoring.

Two monitors, one for control functions, the other for graphic functions, afford distinct advantages over the single-monitor configuration. Maps and/or time history plots will stay in view as the instructor uses a lesson plan page or any other control page. Again, permanent areas can be defined on both monitors, supplying much used information at all times, eliminating almost completely the need to change CRT pages in a lesson plan mode. More than two monitors become undesirable when trying to position them without having the instructor repeatedly turning around; moreover no redistribution of functions would make a three-monitor configuration more efficient, but would certainly add to the cost.

### 7.3.2 Alternative Display System Study

7.3.2.1 CRT Requirements. The minimum requirements call for four independent monitors: two assigned control functions, two assigned graphical functions. Each control monitor must be able to display a minimum of 40 lines by 80 columns of ASCII characters, have at least two distinct levels of brightness or a selection of different colors, and be able to output a control CRT page within two seconds. Each graphics monitor must be capable of drawing points and vectors as well as rotating special symbols. Both the control and graphics monitors must be flicker-free and have a large usable viewing area and good image quality.

Some of these requirements are consequences of load factors placed on the user rather than software design requirements. Flicker, poor image quality, and crowded information on the CRT present a strain on the user, if not over short periods of time, certainly over longer periods.

Brightness levels or different colors assigned to specific parameter states reduce the load on the user when searching through a CRT display for that certain state.

7.3.2.2 General Consideration. Table 7-1 lists all of the CRT systems manufacturers who were requested to provide information about their products. Up to this date, information has been received from all those marked with an asterisk.

The products available can be divided into two major groups, raster scan and calligraphic. Within the group of raster scan type display systems, the majority of manufacturer's products can be eliminated from competition immediately for not meeting the following minimum requirements:

- 40 lines by 80 characters minimum capability
- Output control CRT page in two seconds
- Point, vector drawing capability

In general, the rejected group of raster scan systems are 24 line by 80 character systems serially interfaced to the host computer.

Other raster scan systems do have many features that satisfy most of the requirements. Some of these are:

- 40 lines by 80 characters
- Point, vector drawing capability
- Special symbol definition
- Parallel interface to host (maximum transfer rates not guaranteed)
- Color capability
- Four independent monitors on one controller

However, these systems do have some basic shorcomings with respect to the graphics formats. In particular, with a contour map having an

aircraft track and several other tracks all being plotted simultaneously, the monitor would present a very crowded picture. The raster scan systems are not high resolution. Vectors drawn are noticeably jagged. Relatively thick line widths also add to the cluttering of the image. Besides the physical limitations mentioned, the software to execute the required programs driving the displays becomes quite involved. Disc files are needed to remember what exactly has been placed on the screen. This arises from the requirement to have a map or time history active but not in view.

It may be suggested that a raster scan system should be used for the two control monitors and calligraphic displays for the two graphic monitors because a raster scan display system costs much less than a calligraphic system. However, since a calligraphic system will usually accommodate up to four monitors, a saving will only be achieved if the cost of the raster scan controller plus host interface plus two CRT's is appreciably less than the two vector display monitors which are saved. The mixture of two types also involves extra software and extra maintenance problems. Overall, it seems more logical and cost effective to use the calligraphic system for all four displays.

TABLE 7-1. LIST OF MANUFACTURERS

| | |
|---|---|
| * | Adage |
| * | Amcomp |
| * | Applied Digital Data Systems |
| * | Ann Arbor Terminals |
| * | Aydin Controls |
| * | Beehive Medical Electronics |
| * | Burroughs |
| | Cincinnati Milacron/Process Controls Division |
| * | Computek |
| * | Computer Optics |
| | Comtal |
| * | Conrac |
| * | Control Data |
| * | CPS |
| * | Datamedia |
| | Datapoint |
| * | Delta Data Systems |
| * | Digi-Log Systems |
| | Digital Computer Controls |
| * | Digital Equipment Corporation |
| | Elta Electronics Industries |
| * | Grinnell Systems |
| * | Genisco Computers |
| | Hazeltine |
| | Hewlett-Packard |
| * | Hughes Aircraft |
| | IBM/Data Processing Division |

TABLE 7-1. LIST OF MANUFACTURERS (Continued)

| | |
|---|---|
| * | Imlac |
| * | Information Displays |
| * | Informer |
| | Infoton |
| * | Intelligent Systems |
| * | International Communications Corporation |
| | Jacguard Systems |
| * | Lear Siegler/Electronics Instrumentation Division |
| | Magnavox Display Systems |
| * | Megadata Computer and Communications |
| * | Microdata |
| * | Mohawk Data Sciences |
| | Motorola Display Products |
| | Nuclide |
| | Omron Information Products Division |
| | Ontel |
| * | Pertec Business Systems Division |
| | Plantronics |
| * | Ramtek |
| | Raytheon Data Systems |
| * | Research |
| * | Sanders Data Systems |
| * | SC Electronics |
| | Sphere |
| * | Sycor |
| * | Tandberg Data |
| * | TEC |
| * | Tektronix |
| * | Teletype |
| | Terminal Communications |
| * | Trixex |
| * | Vector General |
| * | Wang Laboratories |
| | Westinghouse Canada |

* Manufacturer responded.

7.3.2.3 Calligraphic CRT Systems. The calligraphic system forms an image by drawing vectors between random points on the CRT. The advantage of the system is that lines are continuous, without the jagged edges characteristic of raster scanned displays. At the same time, finer line widths than those obtained from raster techniques are possible. However, for color display, conventional shadow mask color CRT's cannot be used with these systems. Instead, beam penetration color tubes are used (paragraph 5.3.2.3.2). These tubes produce a limited variety of colors, normally red, orange, yellow, and green, and the brightness of the color image is a function of the writing speed. As a result, it is not easy to fill the screen with bright, multicolor data in a normal scan time. These systems are therefore best used with black-and-white monitors.

The calligraphic system forms a refresh image by constantly executing a display file. For different systems, this file may exist in the host computer or be contained in the display system. If the refresh file is resident in the host, the input/output (I/O) system is loaded down by the continual transfer (via DMA) of the complete refresh file to the display system at the refresh rate.

Therefore, a system with its own internal memory is preferred since I/O time is minimized, the system consisting of volatile update information only and becoming heaviest during new format calls. Table 7-2 lists the display systems that were considered to satisfy the instructor station display system requirements and lists some of their characteristics, which are used in the following comparison.

As far as the physical characteristics of the visual display are concerned, all of the display systems satisfy the basic requirement of producing a crisp, quality image in a large viewing area. The Graphic 7 has more workable screen size for this application and also a faster phosphor, giving it a small edge over the others.

All of the display systems in Table 7-2 have adequate software capability to meet the alphanumeric and graphic format requirements. Appendix D, which is a refresh timing analysis for a Graphic 7 configuration, indicates that the information on the display at any time is composed mostly of ASCII characters and short vectors. None of the display systems is as fast as the Graphic 7 in executing ASCII characters. Where it takes the Graphic 7 approximately 6.8 ms to write all the characters and short vectors on the screen for high density displays shown on Figures 7-1 and 7-2, the next best time is 9.3 ms for the Vector General 3404. Although a complete timing analysis was not performed for each of the display systems, preliminary calculations indicate that for the type of information to be displayed, the Graphic 7 is clearly superior to most systems and, in the case of Vector General, may be marginally faster.

The following factors were taken into consideration when deciding to make the Sanders Graphic 7 the recommended display system for the instructor stations:

- Image quality
- Instruction set
- Instruction execution times
- CPU to Graphic 7 interface
- Internal microprocessor capabilities
- Cost
- Previous experience

A detailed specification is reproduced in Appendix E.

TABLE 7-2. DISPLAY SYSTEMS

| MANUFACTURER | SANDERS GRAPHIC 7 | ADAGE GP/400 | VECTOR GENERAL 3404 | INFORMATION DISPLAYS IIDIOM II SERIES 72 |
|---|---|---|---|---|
| Viewing Area (Max) | 12 X 16 in. | 13 X 14 in. | 13 X 14 in. | 13 X 13 in. |
| Line Width, Spot Size | .02 in. | .02 in. (.15 in. opt.) | .02 in. (.01 in. opt.) | |
| Phosphor | P31 | P40 | | P40 |
| Character Write Time (Avg.) | 3 μsec | 7 μsec | 5.5 μsec | 5 μsec |
| Line Drawing Time | 2.4 to 41 μsec | 3.0 to 17.5 μsec | 20,000 0.1 in. vectors at 30 Hz (i.e., 1.67 μsec) | 5.0 to 30.0 μsec |
| Previous Manufacturer Product Experience | ADDS 720 ADDS 500, Graphic 7 (proposed) | None | None | None |
| Approx. Equivalent System Cost US$ | 62,000 | 80,000 | 80,000 | 100,000 |

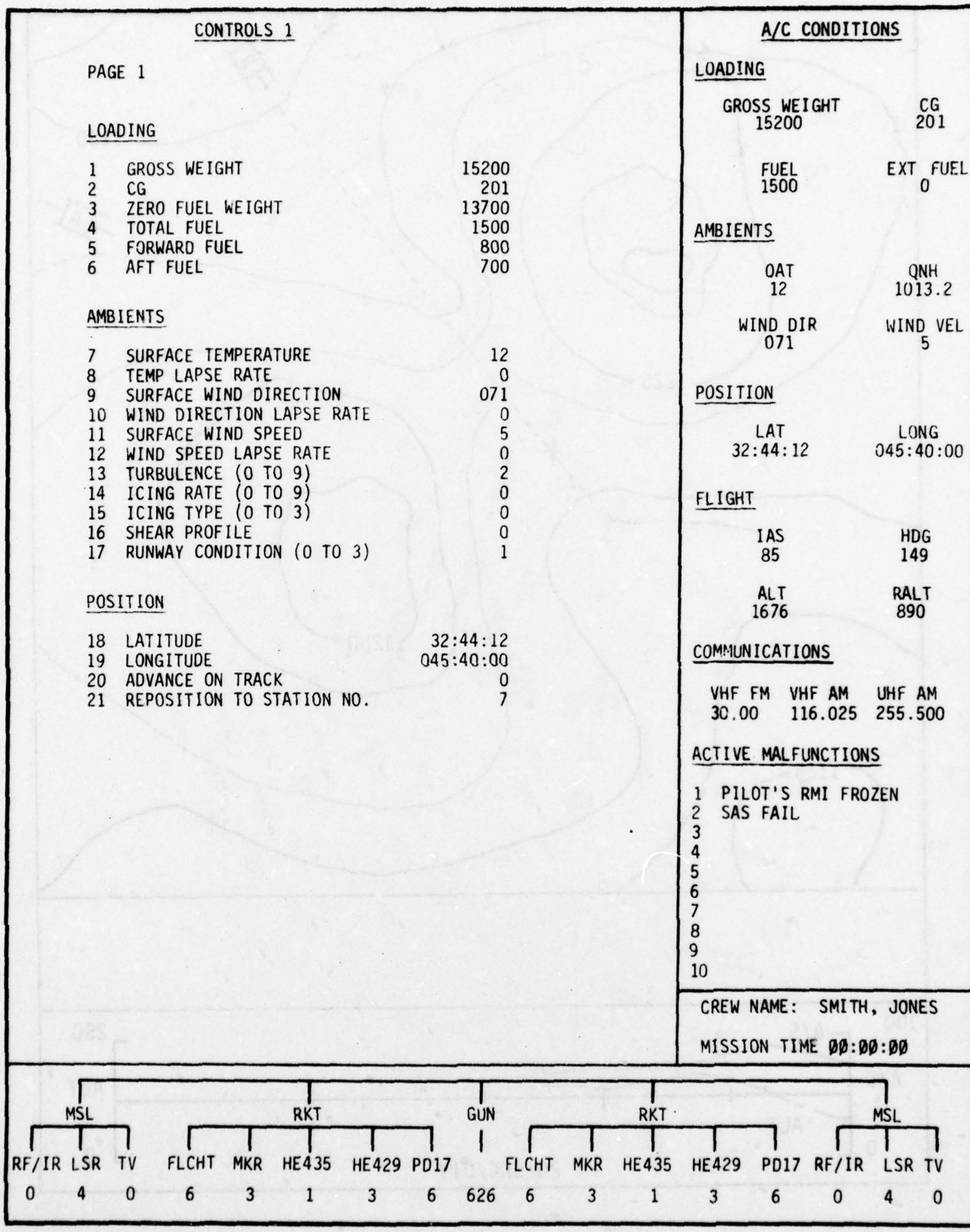



Figure 7-1. High-Density Control Display

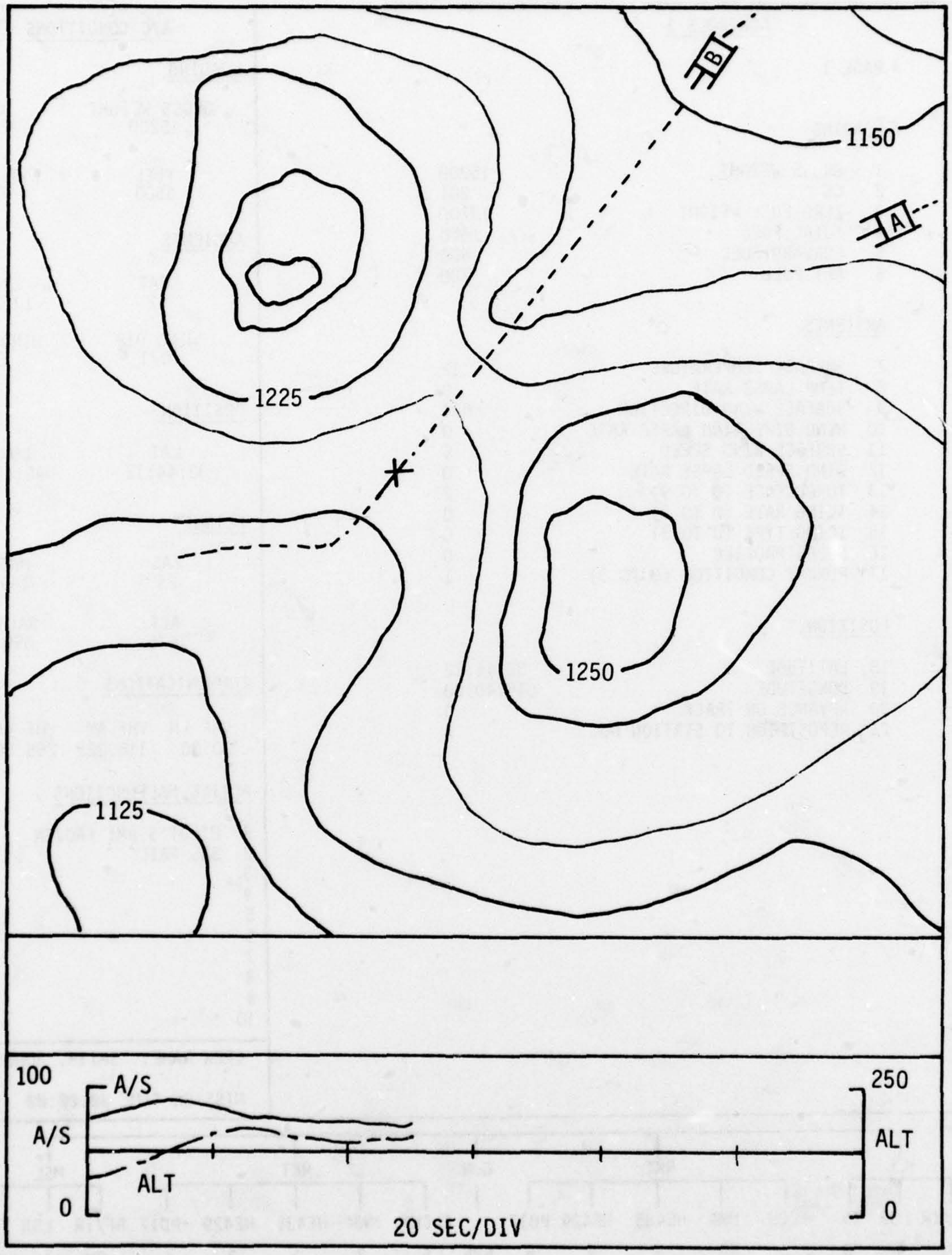



Figure 7-2. High Density Graphic Display

7.3.2.4 Recommended Hardware Configuration. The recommended display system configuration is shown in Figure 7-3, and a component list is shown in Table 7-3. The terminal controller contains the display processor, 8K of 16-bit word memory, ROM control program/self test, graphic controller, vector position generator, stroke character generator, and dual output channel. The additional 8K of memory is specified, based on the memory estimates of Table 7-4. The parallel interface provides data transfer rates of up to 500,000 words/second between the main computer and the Graphic 7. The special symbol design and 32 special symbols options provide for all the map symbols, including those for the contour scale. The coordinate converter is used to rotate individual symbols, which is especially useful in presenting the map contour scale special symbols. The 21-inch monitors are supplied with a P31 green phosphor and are 12 inches wide by 16 inches high.

7.3.2.5 Color Monitors. One Graphic 7 controller will only drive two beam penetration color monitors. Therefore, even if only one monitor at each instructor station is color, two controllers are required, adding approximately $24,000 to the configuration cost (Table 7-3). The color monitors themselves are $5,000 more than the suggested monochrome, adding $10,000 for two and $20,000 for four color monitors. This brings the display configuration hardware cost up to $95,700 for one color monitor at each station and $105,700 for two at each station. The color monitor image is not as bright as the monochrome. The line quality is about the same, but each color has different refresh rates. The writing speed on the red phosphor must be slowed down to 40% of regular speed, the green 50%, and the yellow 75%. At these writing speeds it may not be possible to run two color monitors off one controller, but the capability of driving one monitor exists. Blinking and various brightness levels can be used in lieu of color, perhaps not as effectively but at a lower cost. At this time, color monitors are not recommended because of the expense involved and the marginal performance.

## 7.4 AH-64 INSTRUCTOR/OPERATOR FACILITIES

7.4.1 General. This paragraph describes an instructor's facility which will minimize the instructor workload and thus allow optimum instructor participation in the training mission. The recommended configuration is based on the criteria developed in paragraphs 7.2 and 7.3 and CAE's previous experience in instructor's facility design.

The proposed facilities are centered around the Sanders Graphics 7 display system for both control of the exercise and display of information.

The proposed configuration calls for an instructor station located behind each trainee, assuming a simulator configuration of separate pilot and copilot/gunner (CPG) cabins on separate motion bases.

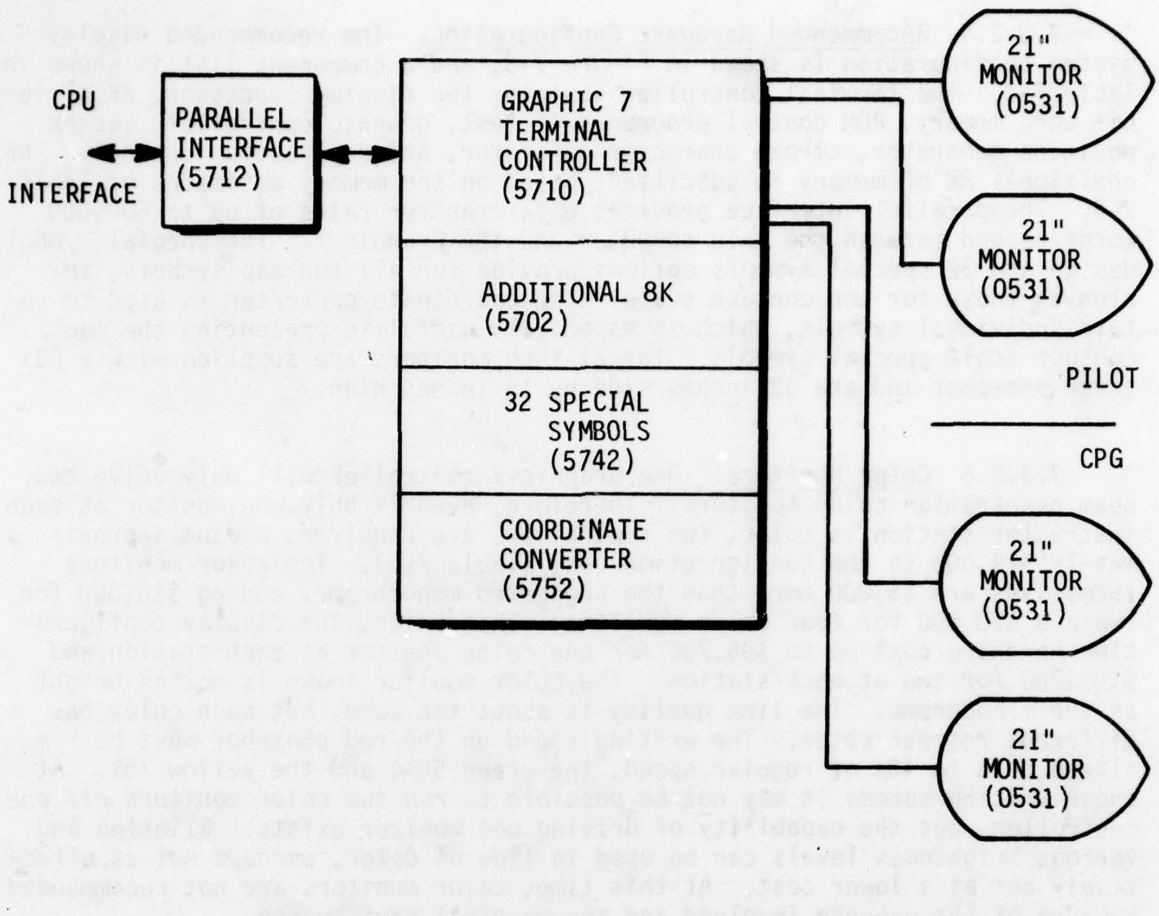



Figure 7-3. Instructor Stations CRT System Configuration

TABLE 7-3. CRT DISPLAY SYSTEM COMPONENT LIST

| QTY. | MODEL NO. | DESCRIPTION | PRICE EACH* | TOTAL |
|---|---|---|---|---|
| 1 | 5710 | Terminal Controller | 23900 | 23900 |
| 1 | 5702 | Additional 8K | 2500 | 2500 |
| 1 | 5712 | Parallel Interface | 3000 | 3000 |
| 1 | 5741 | Special Symbol Design | 2000 | 2000 |
| 1 | 5742 | 32 Special Symbols | 500 | 500 |
| 1 | 5752 | Coordinate Converter | 5000 | 5000 |
| 4 | 0531 | 21-inch Monitor | 6200 | 24800 |
| | | | TOTAL | 61700 |

* Per Sanders Graphic 7 price schedule, effective Sept. 1, 1976

TABLE 7-4. GRAPHIC 7 MEMORY BREAKDOWN

| | | |
|---|---|---|
| Pilot Control Display | In View | 1.5K |
| | Background | 1.5K |
| CPG Control Display | In View | 1.5K |
| | Background | 1.5K |
| Pilot Graphic Display | In View | 2K |
| | Background | 2K |
| CPG Graphic Display | In View | 2K |
| | Background | 2K |
| Applications Software | | 1K |
| Spare | | 1K |
| | TOTAL | 16K |

This paragraph contains a recommended format for the CRT display system information, detailing control page and graphical layouts. Types of graphical presentation and their use are discussed and the implementation of recommended utilities and devices explored. Also included are suggested panel layouts to allow facility operation with low complication.

7.4.2 CRT Display Formats and Recorders. It is proposed that each instructor position be supplied with two CRT's, one assigned a control function, the other displaying graphical information (e.g., maps, time histories, etc.). This configuration allows control functions to be performed without disturbing any graphical presentation. The design objectives for the CRT display system are:

(a) To present the maximum amount of useful information without crowding.

(b) To allow control of simulator variables via CRT pages in such a manner that minimum instructor workloading is incurred.

Where applicable, the design features are in accordance with MIL-STD-1472B.

A large usable area on each display (12" x 16") permits dividing the CRT screen into transient and permanent areas. The transient areas present the various CRT pages, maps, and so on, whereas the permanent areas provide a continuous display of much used information.

New CRT page requests are processed promptly to produce a new display within two seconds (also refresh rate) and, in special cases, instantaneously.

The capability of hardcopying any display is provided, and it is not required that the CRT page be in view at the time of the request.

7.4.2.1 CRT Control Display Format. The control display CRT formats are sectioned into a permanent and a transient area. Figure 7-4 shows the control display format dimensions. The permanent area may be used to provide a continuous update of aircraft (A/C) conditions, wing stores status, and a list of the active malfunctions.

The A/C conditions area, on the right hand side of the display, can provide A/C loading, ambients, A/C position, flight data and selected communication frequencies data for the instructor. A list of the malfunctions up to a maximum of ten, given in plain English or abbreviations is also available to the instructor. The wing stores status section tells the instructor what is on the wing pods.

The transient area is used to display the various CRT pages which the instructor may call into view, using the direct page select controls or a line input on an index page. Table 7-5 is a list of the recommended CRT pages, the system having a total capacity of at least 400. Input to or control of simulator parameters is effected through the transient area (CRT page), using the DIRECT LINE SELECT pushbuttons for line selection (maximum 30 I/P lines per CRT page) and the instructor's keypack for subsequent data entry where required. Figure 7-1 is an example of a CRT page which has 21 input lines.

The pages display simulator volatile data. A plain English comment that describes the parameter accompanies each volatile item. Each parameter value is monitored for change at least every two seconds, and subsequent display update is performed if required.

The following CRT pages are instantaneously available (within 1/2 second to display) at all times: the previously displayed CRT page and the active lesson plan page. Normal page requests are serviced within two to four seconds, depending on page size and number of display fields.

7.4.2.2 Graphical Display Format. Similar to the control display formats, the graphics display formats are sectioned into a permanent and transient area. Figure 7-5 shows the recommended graphics display format dimensions. The permanent area provides a continuous time history plot of two parameters (e.g., airspeed and altitude above ground) and an engagement summary.

TABLE 7-5. CRT PAGES TITLE LIST

| PAGE TITLE | QUANTITY |
|---|---|
| MAIN INDEX | 1 |
| SYSTEMS VARIABLES INDEX | 1 |
| PERFORMANCE EVALUATION INDEX | 1 |
| CHECKLIST INDEX | 1 |
| EMERGENCY PROCEDURES INDEX | 1 |
| MALFUNCTION INDEX | 1 |
| LESSON PLAN INDEX | 1 |
| CONTROLS | 3 |
| POSITION AND MAPPING | 1 |
| RADIO STATION DATA | 1 |
| RECORD AND PLAYBACK | 1 |
| GCA | 1 |
| UNUSUAL ATTITUDES | 1 |
| TIME HISTORY CONTROLS | 2 |
| MALFUNCTIONS | 10 |
| CHECKLIST | 5 |
| SYSTEM VARIABLES | 10 |
| LESSON PLANS | 30 |
| MANEUVER DEMONSTRATION | 1 |
| PERFORMANCE EVALUATION | 20 |
| EMERGENCY PROCEDURES | 5 |
| MANEUVER EDIT | 1 |
| PERFORMANCE EDIT | 2 |
| TOTAL | 101 |

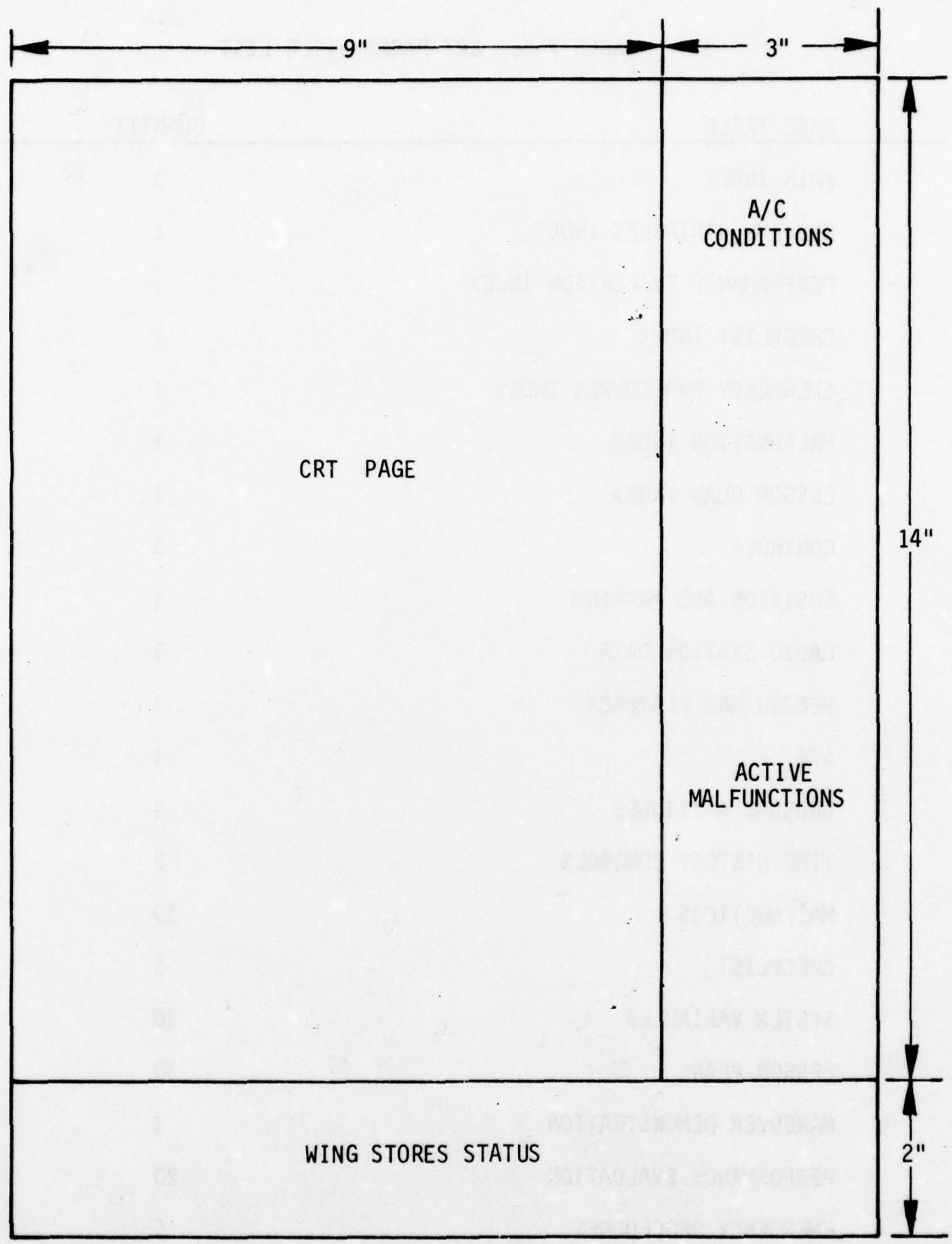



Figure 7-4. Control Format Dimensions

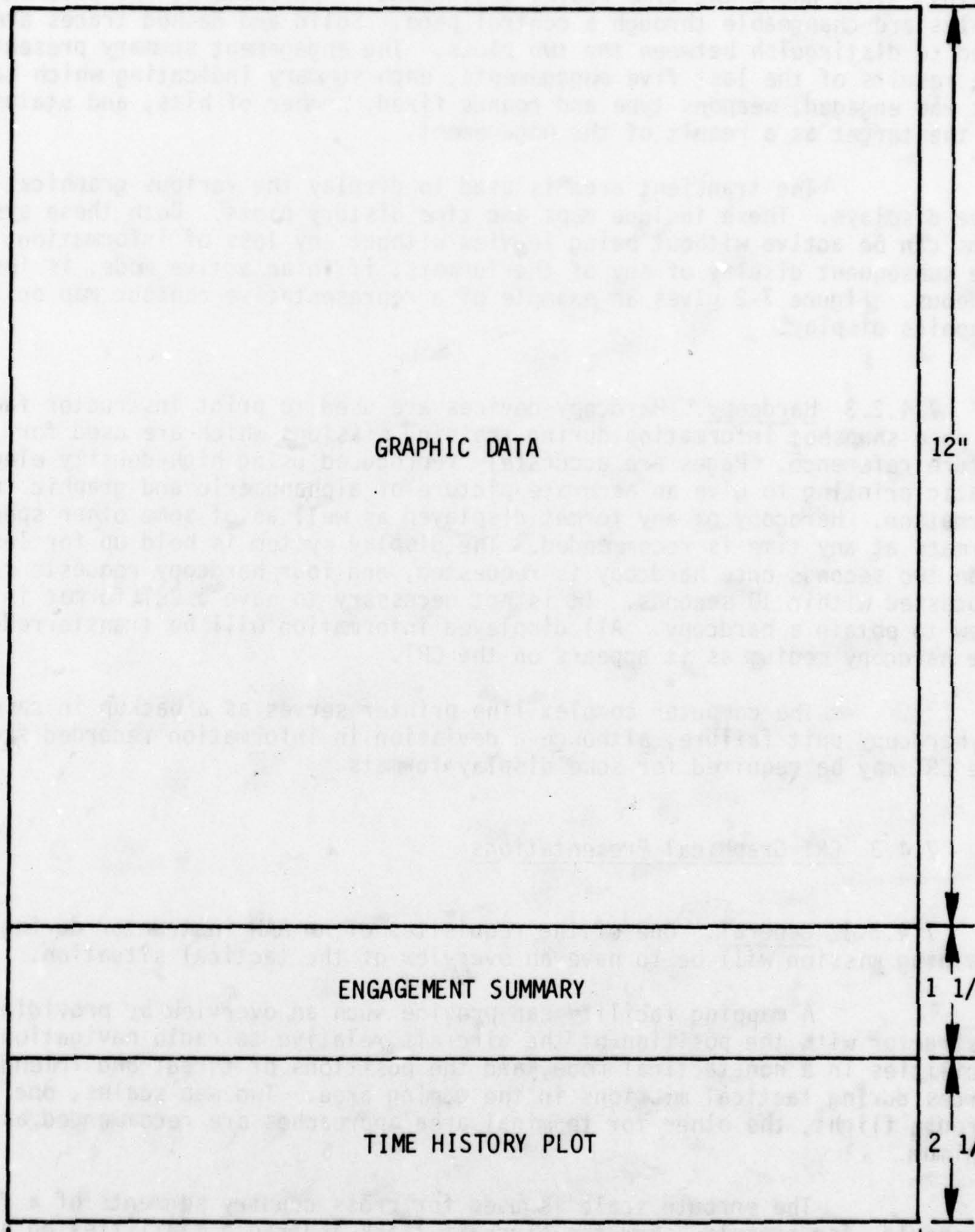



Figure 7-5. Graphics Format Dimensions

The time history plot is capable of plotting two parameters against time, where the time scale, assignment of parameters, and parameter scales are changeable through a control page. Solid and dashed traces are used to distinguish between the two plots. The engagement summary presents the results of the last five engagements, each summary indicating which target was engaged, weapons type and rounds fired, number of hits, and status of the target as a result of the engagement.

The transient area is used to display the various graphical type displays. These include maps and time history plots. Both these systems can be active without being in view without any loss of information, and the subsequent display of any of the formats, if in an active mode, is instantaneous. Figure 7-2 gives an example of a representative contour map on the graphics display.

7.4.2.3 Hardcopy. Hardcopy devices are used to print instructor facility page snapshot information during training missions which are used for future reference. Pages are accurately reproduced using high-density electrostatic printing to give an accurate picture of alphanumeric and graphic information. Hardcopy of any format displayed as well as of some other special formats at any time is recommended. The display system is held up for less than two seconds once hardcopy is requested, and four hardcopy requests can be processed within 10 seconds. It is not necessary to have a CRT format in view to obtain a hardcopy. All displayed information will be transferred to the hardcopy medium as it appears on the CRT.

The computer complex line printer serves as a backup in case of hardcopy unit failure, although a deviation in information recorded from the CRT may be required for some display formats.

### 7.4.3 CRT Graphical Presentations

7.4.3.1 General. One of the requisites of an AAH instructor during a training mission will be to have an overview of the tactical situation.

A mapping facility can provide such an overview by providing the instructor with the position of the aircraft relative to radio navigation facilities in a non-tactical mode, and the positions of threat and friendly forces during tactical missions in the gaming area. Two map scales, one for enroute flight, the other for terminal area approaches are recommended as a minimum.

The enroute scale is used for cross country segments of a flight. It should, for example, show the aircraft track and radio facilities on a 20nmi/in scale. A terminal scale of 5nmi/in should also display the aircraft track and radio facilities, in addition to supplying the instructor with enough information to direct a GCA approach, such as height above or below glideslope

and feet left or right of the runway. Any latitude and longitude combination should be acceptable for map center.

A contour scale should fulfill a need for the instructor to know, relative to the aircraft, where threat and friendly forces are located and at which ground level. Contour lines at 25-, 50-, or 100-foot intervals, plus special features such as rivers and bridges, should be displayed to provide the instructor with enough detail to evaluate the aircraft position relative to threat or friendly positions. Special symbols should be used to describe the various hardware which could be encountered in the gaming area. The symbols should be clearly defined, so that different hardware can easily be identified. Threat and friendly hardware can be distinguished by assigning each a separate color making the threat symbols double bright. The contour scale should clearly indicate when the aircraft is in the line of sight of any threat. Mask and unmask times should be recorded. The distance from the center of the map to any boundary should be at least equal to the distance within which the crew can detect threat forces.

It would be very useful for the instructor to have the ability to look at any portion of the gaming area to monitor the threat configuration. There are two ways to accomplish this. One way is to provide a contour center slew whereby the display monitor becomes a moving window. However, to execute this feature properly that is, to have the map move quickly and smoothly, the total gaming area contour description, including threat and friendly forces special symbols, must be contained in the display controller memory at all times. A special applications program would also have to be executed by the internal microprocessor of the display system. This is not an ideal approach from the point of view of implementation, since much more display memory is required, and while the microprocessor is executing, it is stealing refresh time. Another technique would be to provide an overview format. This would cover the whole gaming area and would show all the threat and friendly forces, but without the contour lines. This format would be stored and updated in the display memory, so that instantaneous access could be made to it at any given time, ideally, via a panel pushbutton. The instructor should have a means of determining quickly and accurately the range and bearing to all the threats in the gaming area. This can be done in the form of an overlay. Lines drawn over the display from the aircraft to the various threats (even those off screen) would have the range in meters alongside. The bearing is not written with the range since magnetic bearing values, as such, may not be applicable; for instance, the instructor may prefer to make an "o'clock" reading. Activation of this feature should be via a momentary-action pushbutton.

Since the main use of the simulator will be in a tactical mission training role, the contour scale controls should be available for quick access on the instructor's panel.

A hardcopy of the contour map could be generated automatically whenever an engagement has occurred, thus providing a record of all engagement configurations for review at the end of a training session.

A time history plotter should be available to plot selectable parameters against time. The facility can be broken down into nontactical and tactical applications. In a nontactical training flight, performance can be recorded by plotting several parameters against time; for example, airspeed, altitude, vertical speed, and torque would be one configuration. In tactical training, parameters such as miss distance, time under fire, time to fire, and time exposed could be plotted to provide a permanent record of performance. Various grid configurations and the capability of changing X and Y axis scales is required.

7.4.3.2 Proposed Mapping Facility. The mapping facility proposed for the FWS plots aircraft, friendly, and threat forces tracks. There are three scales, enroute terminal, and contour, and the map center may be at any latitude and longitude. The map is always active, and a hardcopy can be requested, even when the map is not in view.

Two scales are provided for non-tactical flight, enroute and terminal:

- The enroute scale (20 nmi/in) plots the aircraft track and radio facilities position (Figure 7-6).
- The terminal scale (5 nmi/in) provides ground control approach (GCA) information in addition to aircraft track and radio facilities (Figure 7-7).

Other features of the mapping facility are:

- The contour scale is used in tactical mission training.
- An area of 5 km by 5 km is displayed at any time (Figure 7-2).
- Threat and friendly forces hardware are plotted by using special symbols as defined in Table 7-6, and threat forces are displayed double bright.
- Identification codes assigned to the various hardware are repeated on the respective symbols displayed.
- The map can be recentered at any time by activating the A/C center pushbutton on the instructor's panel or game area center pushbutton.
- Whenever the aircraft and a threat force are in line of sight, a dashed line appears between the two symbols displayed.
- The aircraft track is marked with a number whenever the aircraft is unmasked

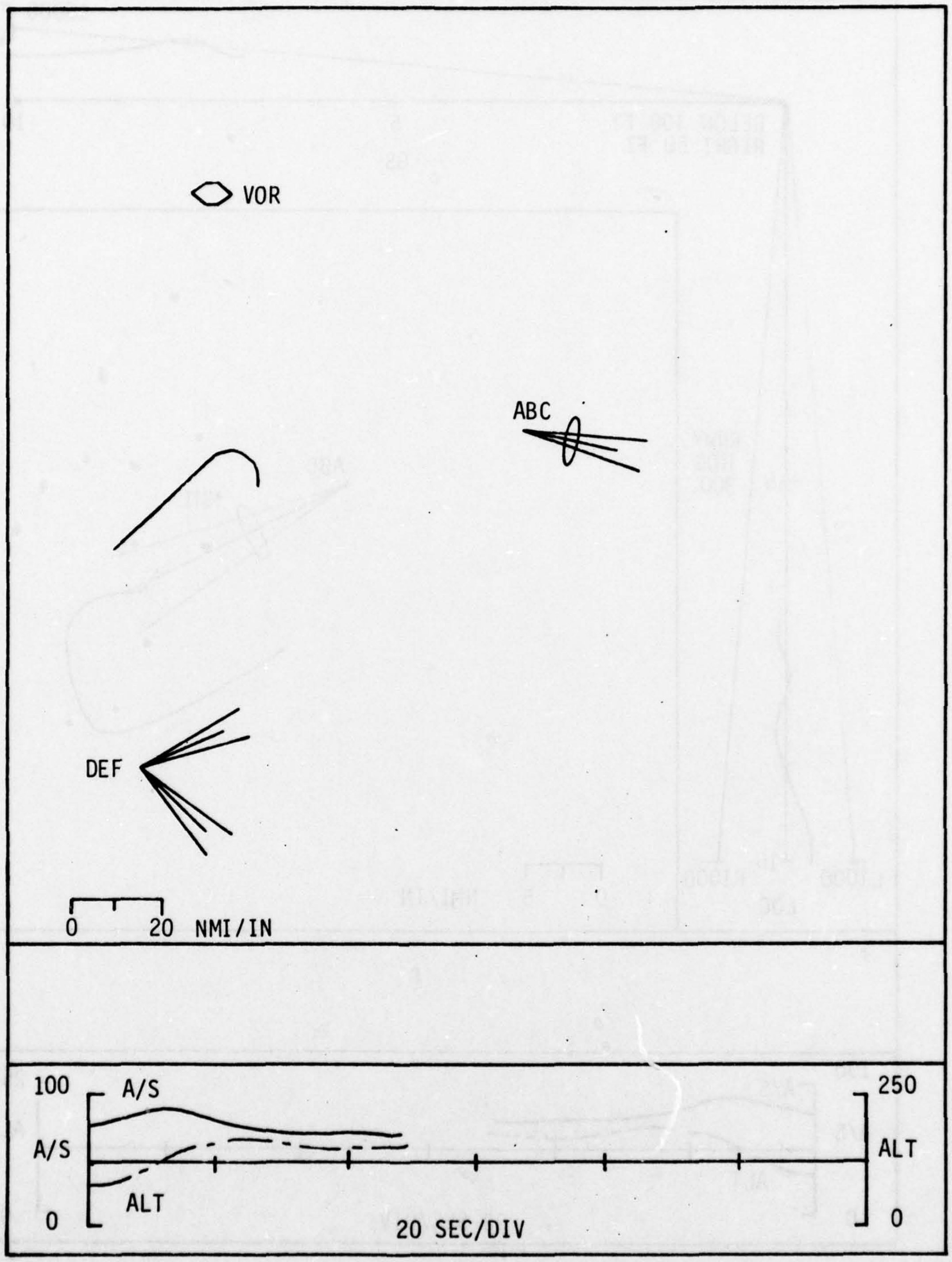



Figure 7-6. Maps - Enroute Scale

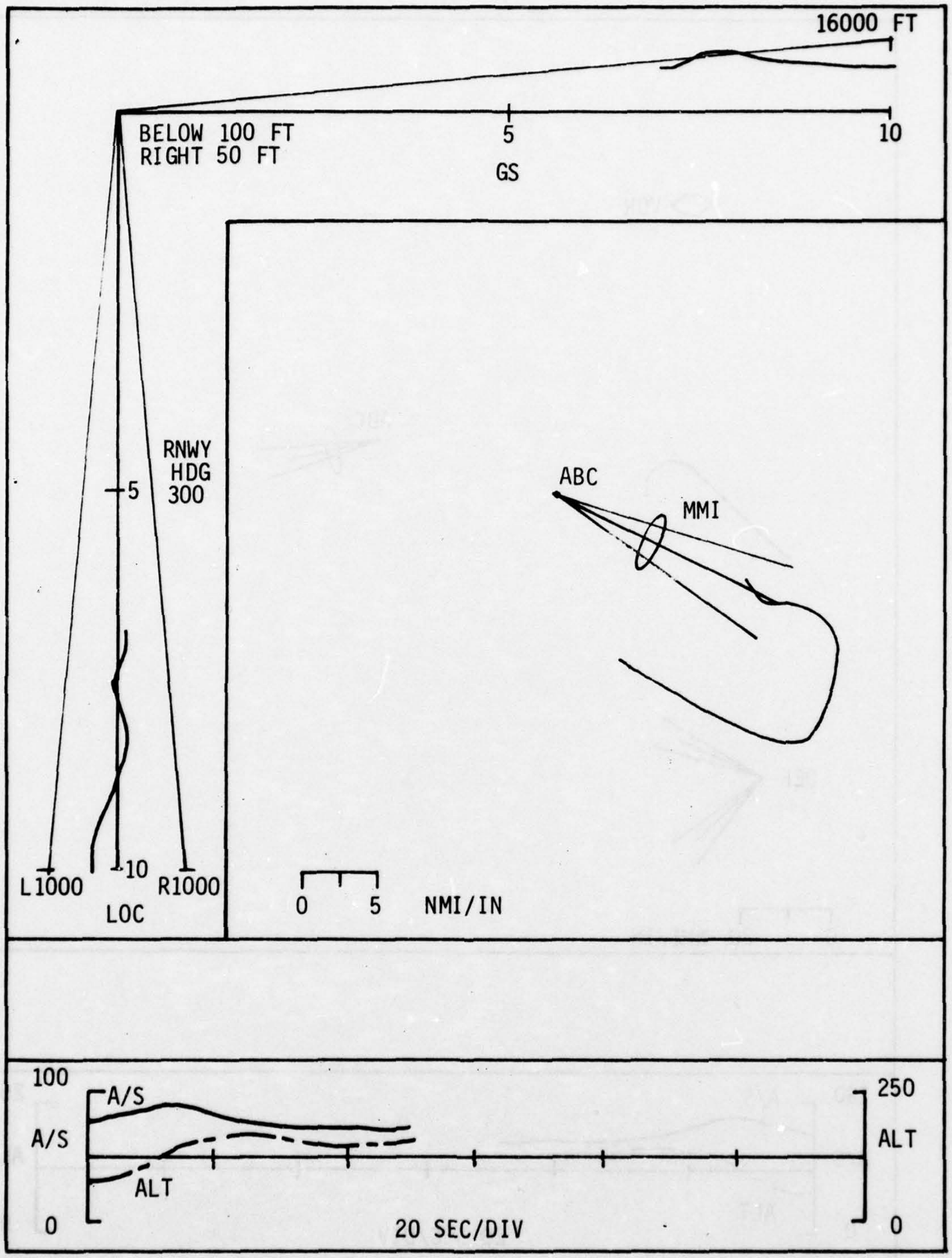
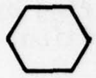
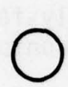
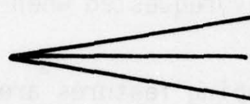


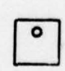

Figure 7-7 Maps Terminal Scale

TABLE 7-6 MAPS SPECIAL SYMBOLS

RADIO NAVIGATION SYMBOLS

| | | | |
|---|---|---|---|
|  | VOR |  | MARKER |
|  | NDB |  | TACAN |
|  | ILS |  | VORTAC |

CONTOUR SYMBOLS

| | | | |
|---|---|---|---|
|  | ATTACK HELICOPTER |  | COMBAT VEHICLES |
|  | TANK |  | ARTILLERY |
|  | ANTIAIRCRAFT MISSILES |  | BRIDGE |
|  | ANTIAIRCRAFT GUNS |  | RIVER |

- A table on the graphics display provides a record of how long (seconds) the aircraft was unmasked at the marked points.

- When depressing the range and bearing pushbutton, an overlay appears on the display, indicating the distance to individual threat positions (meters) and the bearing by drawing lines from the aircraft to each threat position.

- When depressing the contour area view pushbutton, an overview display, showing all threat and friendly forces positions in the gaming area, replaces the contour map until the pushbutton is released.

A hardcopy of the contour map is automatically requested whenever an engagement has taken place.

The map controls required to activate all mapping features are itemized in Table 7-7 and illustrated in Figure 7-8.

TABLE 7-7. MAP CONTROLS

| PUSHBUTTON | FUNCTION |
|---|---|
| ENRTE | Selects the enroute scale (20nmi/in). |
| TERM'L | Selects the terminal scale (5nmi/in). |
| CTR | Selects the contour scale. |
| A/C | Centers the map at the present position of the aircraft |
| GAME AREA | Centers the map at the center of the gaming area. |
| RANGE AND BRNG. | Momentary-action switch. Calls range and bearing overlay. |
| CTR AREA VIEW | Momentary-action switch. Calls game area threat and friendly forces overview. |
| VIEW MAP | Calls the presently activated map into view |
| H/C MAP | Requests a hardcopy of the presently activated map. |
| TRACK ERASE | Momentary-action switch. A/C track (and target tracks on contour scale) is erased slowly while this pushbutton is depressed. |

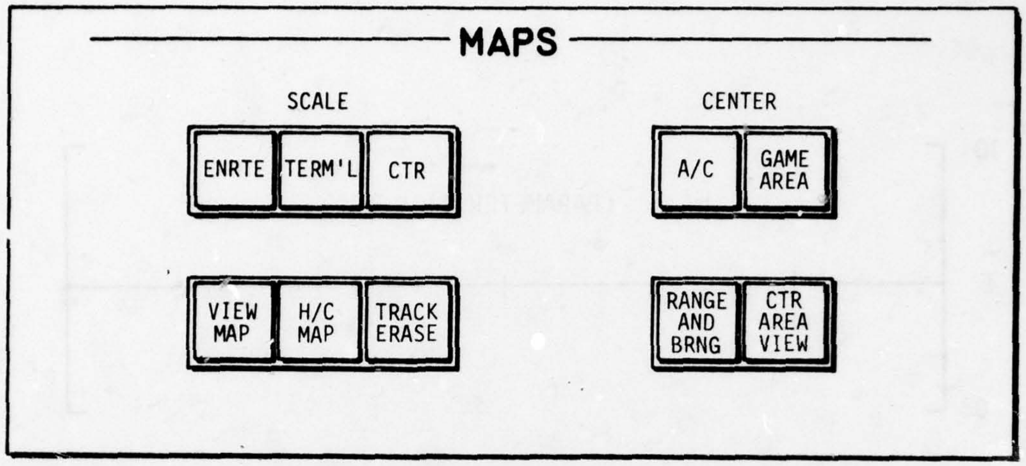



Figure 7-8. Maps Control Panel

7.4.3.3 Proposed Time History Plotter. The time history plotter facility enables the plotting, against time, of up to as many as four parameters simultaneously, which are selected from a menu of 100.

Three selectable grid configurations are available for plotting one, two or four parameters at a time (Figure 7-9 shows one configuration). The mean and max (Y-axis) values are specified for each parameter by the instructor along with the time scale (X-axis) through a CRT page.

The start of plotting can be activated from the instructor's panel directly or activated by a preselect. In the latter case, plotting will commence when instructor specified values for altitude and/or airspeed and the respective aircraft values correspond. It is not required that the plot format be in view for plotting to occur.

Controls for view plot, plot erase, and hardcopy plot appear on the instructor's panel. Hardcopy and erase may be activated without the plot in view.

It will be possible to have all time history parameters controlled through the lesson plan, thus reducing the instructor work load during training.

Sample parameters are listed in Table 7-8 and the instructor controls itemized in Table 7-9 and illustrated in Figure 7-10.

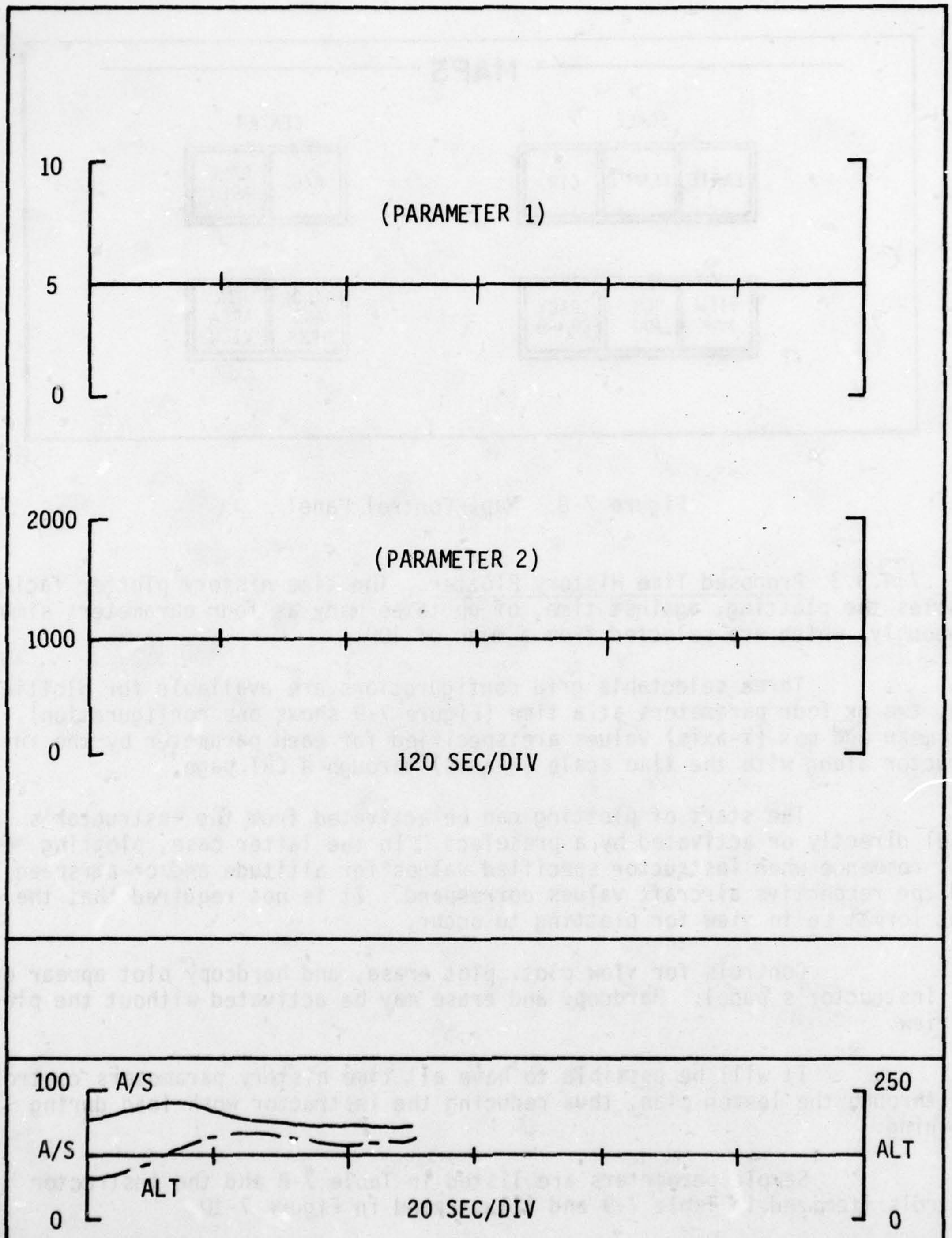



Figure 7-'9. Time History Grid

TABLE 7-8 TIME HISTORY PLOTTER MENU

| ITEM | DISPLAY NAME | PARAMETER DESCRIPTION |
|---|---|---|
| 1 | AIRSPEED | INDICATED AIRSPEED (KTS) |
| 2 | HEADING MAG | MAGNETIC HEADING (DEG) |
| 3 | PRESS ALTITUDE | PRESSURE ALTITUDE (FT) |
| 4 | VERTICAL SPEED | VERTICAL SPEED (FT/MIN) |
| 5 | RADAR ALT | RADAR ALTITUDE (FT) |
| . | | |
| . | | |
| . | | |
| up to 100 | | |

TABLE 7-9 TIME HISTORY PLOTTER CONTROLS

| PUSHBUTTON | FUNCTION |
|---|---|
| Start Plot | Starts/stops plotting of instructor selected parameters. |
| Erase Plot | Removes all traces from time history plot format. |
| Hardcopy Plot | Produces a hardcopy of the plot as it exists at that instant in time. Plot format need not be in view. |
| View Plot | Calls time history format into view if it is not already in view. |

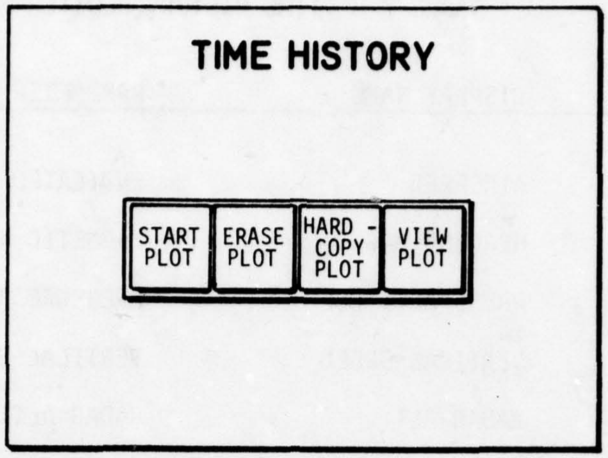



Figure 7-10. Time History Plotter Controls

7.4.4 Instructor Utilities. The recommended instructor utilities are proposed to enable the instructor to have complete control over the simulator training mission and yet dedicate sufficient time to evaluation of student performance. The utilities include those systems designed to relieve the instructor's workload through the extensive use of a library of lesson plans which provide a set mission sequence advanced step by step under the instructor's control. Several examples are:

- Record and playback for more detailed mission execution analysis.
- Maneuver demonstration, allowing prerecorded missions to be demonstrated.
- Tactical situation control, giving the instructor the ability to maneuver threat and friendly forces.
- Automated initialization routines, allowing condition and position setups of the AH-64 and threat environment.

7.4.4.1 Simulator Initialization, Recording and Demonstration Facilities

7.4.4.1.1. General. The record and playback can be implemented in two ways. One method is to have the recording running continuously, with a total capacity of n minutes, thus making the last n minutes of a simulator performance available for playback, the amount of time allotted depending on the storage space available. Another technique would be to have a number of

segments of recording time which are activated when desired. The second option has two obvious advantages. First, the total record time available, and thus storage space, is more efficiently used because unimportant mission segments are not recorded. Second, key phases of a training mission can be recorded selectively without destroying previous recorded phases.

The playback should have a normal and a slow speed. No significant hardware or software effort is required to play back in slow speed, and the feature allows the instructor time to analyze and comment on fast sequences of events for trainee debriefing. The playback should occur in the cockpits originally recorded except when in the independent mode, where the playback occurs in the cockpit that requested it. A flyout capability should be available during playback to allow the trainee to return and re-try specific portions of a mission that may have caused him difficulty, under exactly the same conditions as previously attempted. This is a quick timesaving method with advantages over the act of going back to the beginning of the exercise. The flyout capability is again limited by the amount of storage space available; hence the interval (every n seconds) can vary. All record and playback controls should be located within easy reach on the instructor's panel for quick access, since this will be a frequently used feature, even in the lesson mode.

A maneuver demonstration is a permanent recording with synchronized briefing and voice commentary added. The demonstrations should be easy to make and be created on-line. The demonstration should be capable of being halted during its course so that the instructor may point out certain features at a particular time or add additional briefing or commentary and then be capable of continuing. Maneuver demonstrations should be replayed into both cockpits when activated, except when in an independent mode, when the demonstration should occur in the cockpit that requested it.

Other features which are based upon record and playback should be included to aid the instructor in initializing the simulator or going back to a selected mission situation. The features are as follows:

- A store/recall facility would enable the instructor to record a number of separate snapshots of mission time such that the aircraft could be returned to those points for quick analysis or for the trainee to fly out of.

- Setups are permanent store/recall's, which should be created on-line. These should provide for a number of conditions from which a selection could be made for simulator initialization.

- Unusual attitudes are short (15 seconds) maneuver demonstrations with flyout. They are intended to fly the trainee into a situation where he is then left to take over. The fly-in gives the trainee time to become familiar with the situation.

The following paragraphs describe recommended configurations that would satisfy the requirements discussed above.

7.4.4.1.2 <u>Record and Playback</u>. The ability to record on disc a total of 30 minutes of aircraft performance is suggested for each cockpit, where the total time may be distributed in any proportion over five selectable segments. Recording may be activated manually from the instructor consoles or automatically in the lesson plan mode.

During playback, all flight compartment movements, indications, and sounds are presented as originally recorded, including motion and visual cues. Voice communications are played back using a synchronized voice recorder, and all primary flight controls are backdriven. Playback is available at two speeds: normal and half speed. At the slow rate, voice and sound playback are suppressed. To provide for independent crew training, single-cockpit playback is provided in a split mode.

Total freeze is available during recording or playback. Accumulated recording time halts during total freeze.

Flyout enables the trainee to take over control of the aircraft at any 10-second interval during playback. An aural message is transmitted over the communications system prior to release of control of the aircraft to the trainee.

Maneuver demonstrations are created on-line, using record and playback in conjunction with the maneuver edit system.

Suggested controls are listed in Table 7-10 and their layout shown in Figure 7-11.

7.4.4.1.3 <u>Maneuver Demonstration</u>. A total of 300 minutes of automatic maneuver demonstration time is suggested, where each demonstration may be from five minutes to 20 minutes long, in five minute increments.

All flight compartment movements, indications and sounds are reproduced as originally recorded, including flight controls and motion and visual cues. Synchronized briefing and voice commentary are provided to accompany each maneuver demonstration.

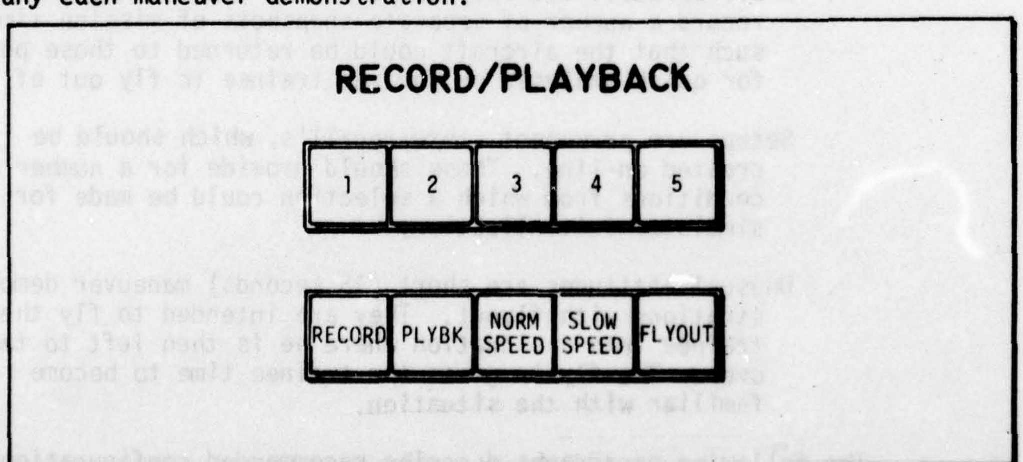



Figure 7-11. Record/Playback Controls

TABLE 7-10. RECORD/PLAYBACK CONTROLS

| PUSHBUTTON | |
|---|---|
| 1,2,3,4,5 | Allow for five individual record/playback segments, each of which may run from 0 to 30 minutes in length, the sum of the segment times being limited to 30 minutes. |
| RECORD | Arms the record mode. When one of the five segment buttons is subsequently selected, recording commences. |
| PLYBK | Arms the playback mode. When one of the five segment buttons is subsequently selected, playback initialization commences. |
| NORM SPEED | Recorded exercise is played back at normal speed. |
| SLOW SPEED | Recorded exercise is played back at slow speed. Sound and communications are not played back in this mode. |
| FLYOUT | Allows flyout from playback at 10-second intervals. |

Demonstration may be activated automatically in the lesson plan mode, or manually, through the CRT page system. Demonstrations may be started at any point by specifying time-to-go and may be terminated at any point. Total freeze is available during demonstration, and demonstration continues when freeze is removed. Maneuver demonstration at slow speed is selected by using the RECORD/PLAYBACK control designated for that purpose.

To create a demonstration, the maneuver is flown as desired, with RECORD/PLAYBACK in the record mode, and then stored on permanent disc file using the maneuver edit page. Voice commentary and briefing are recorded on the voice recorder to playback in synchronization with the flight. All maneuver creation is done with the simulator on-line.

Demonstrations may be single or dual cockpit oriented to provide for individual crew training.

7.4.4.1.4 Store/Recall. The capability of storing on disc five individual simulator configurations at any time during training for each cockpit is suggested. Control is effected through the instructor console.

Recall reconfigures all flight compartment systems, including motion and visual, as they existed at 'store' time. Total freeze occurs when the reconfiguration is completed, and upon release of total freeze, control of the aircraft is taken over by the trainee (flyout).

Suggested controls are listed in Table 7-11 and panel layout shown in Figure 7-12.

TABLE 7-11. STORE/RECALL CONTROLS

| PUSHBUTTON | FUNCTION |
|---|---|
| 1,2,3,4,5 | Allow for five individual 'snapshots' of the simulator configuration |
| STORE | Arms the store mode. When one of the five buttons is subsequently selected, the simulator configuration is stored on disc. |
| RECALL | Arms the recall mode. When one of the five buttons is subsequently selected, the simulator will assume the configuration that was stored on disc in the respective slot. |

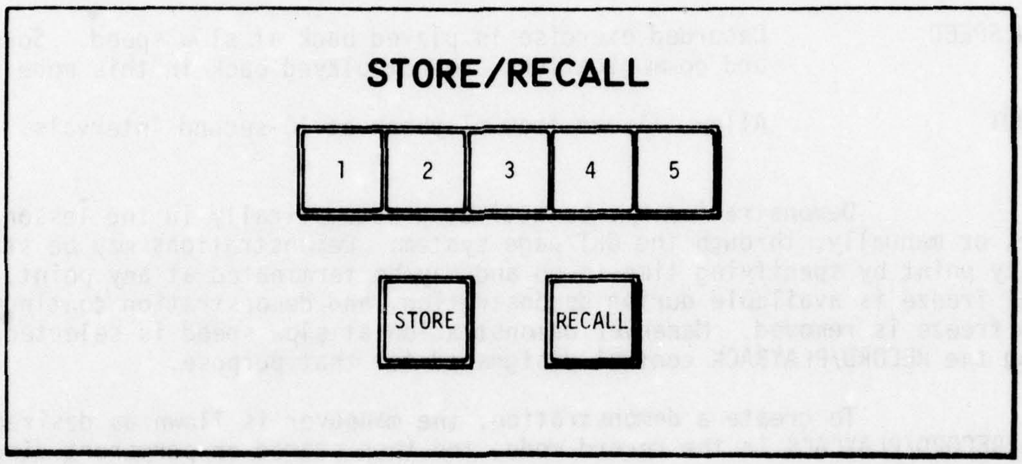



Figure 7-12. Store/Recall Controls

7.4.4.1.5 Unusual Attitudes. The ability to store on disc 10 individual 30-second demonstrations is suggested for each cockpit. At the end of the demonstration, a 'takeover' message is transmitted over the aircraft communica- ations system and then the trainee assumes full control of the aircraft. Con- trol is effected manually through the CRT page system or automatically through a lesson.

Preparation of unusual attitudes is identical to the procedure for maneuver demonstrations.

7.4.4.1.6 Setups. The capability of storing on disc 20 individual con- figurations for each cockpit is suggested. Control is effected through a CRT control page. See paragraph 7.4.4.1.4, Store/Recall for effects of activation.

7.4.4.2 Performance Measurement Aids.

7.4.4.2.1 General. Performance measurement aids are desirable to supplement time history and map displays and aid the instructor in his trainee evaluation. The aids recommended for the FWS are as follows:

- Emergency procedures summary
- Checklist verification
- Performance evaluation
- Tactical mission evaluation

The emergency procedures summary and checklist evaluation relieve the instructor of monitoring switch and control positions, timing sequence of events, and estimating trainee performance of the task. The simulator software is geared towards position monitoring by its very nature. An auto hardcopy feature could be implemented, providing a permanent record of performance.

Present performance evaluation systems are oriented towards IFR and VFR procedures. The system compares aircraft parameters with prespecified standard values to achieve a time-in tolerance result and providing a plain language report. CAE has implemented this system successfully on four previous helicopter simulators.

The tactical mission evaluation, however, is intended for weapons delivery and survivability evaluation. The problem of implementing such a system in the AH-64 is that of establishing the optimum performance criteria. In the absence of any hard and fast rules, it is possible to provide a flexible tool that will allow the customer to choose the parameters and tolerances applicable to a given situation. It is required that all the evaluation reports provide meaningful output, using plain language where possible.

7.4.4.2.2 Emergency Procedures. A possible performance evaluation utility is the emergency procedures utility.

This utility is used to record and evaluate the timing and sequence of events during a trainee's execution of an emergency procedure. Each monitored event is listed on a CRT control page, alongside which appears the order in which the event occurred and the time elapsed since the activation of the malfunction. If the events are performed in the order specified, SEQUENCE-GOOD appears at the bottom of the page. If the time to complete the procedure is within a specified value, TIMING-GOOD appears at the bottom of the page. Otherwise, BAD appears in place of GOOD. Figure 7-13 is a sample emergency procedure.

| PAGE 62 | ENGINE RESTART DURING FLIGHT | |
|---|---|---|
| ON SEQ/TIME | EMERGENCY PROCEDURE CHECK | |
| 1/00:28 | ENG COND LEVER | - GROUND |
| | FIRE CONTROL HANDLE | - IN |
| 2/00:33 | BOOST PUMP SW'S | - ON |
| 3/00:39 | X-FEED SEL | - OPEN |
| 6/01:03 | IGNITION SW | - ON |
| 4/00:41 | START FUEL SW | - OPEN |
| 5/00:43 | START BUTTON | - DEPRESSED |
| 7/01:24 | START FUEL SW | - CLOSE |
| | ENG OIL PRESS | - CHECK |
| 8/01:45 | ENG COND LEVER | - FLT |
| 9/01:58 | ROTOR RPM | - NORM |
| 10/02:27 | TORQUE | - MATCHED |

SUMMARY  SEQUENCE - BAD
TIMING GOOD

**A/C CONDITIONS**

LOADING

| GROSS WEIGHT | CG |
|---|---|
| 15200 | 201 |
| FUEL | EXT FUEL |
| 1500 | 0 |

AMBIENTS

| OAT | QNH |
|---|---|
| 12 | 1013.2 |
| WIND DIR | WIND VEL |
| 071 | 5 |

POSITION

| LAT | LONG |
|---|---|
| 32:44:12 | 045:40:00 |

FLIGHT

| IAS | HDG |
|---|---|
| 85 | 149 |
| ALT | RALT |
| 1676 | 890 |

COMMUNICATIONS

| VHF FM | VHF AM | UHF AM |
|---|---|---|
| 30.00 | 116.025 | 255.500 |

ACTIVE MALFUNCTIONS

1 PILOT'S RMI FROZEN
2 SAS FAIL
3
4
5
6
7
8
9
10

CREW NAME: SMITH, JONES

MISSION TIME ØØ:ØØ:ØØ

| MSL | | | RKT | | | | | GUN | RKT | | | | | MSL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF/IR | LSR | TV | FLCHT | MKR | HE435 | HE429 | PD17 | | FLCHT | MKR | HE435 | HE429 | PD17 | RF/IR | LSR | TV |
| 0 | 4 | 0 | 6 | 3 | 3 | 6 | | 626 | 6 | 3 | 1 | 3 | 6 | 0 | 4 | 0 |

Figure 7-13. Emergency Procedure

7.4.4.2.3 Checklist Verification. This facility monitors switch/control positions and flags those not in the same state as specified. The system is always executing. Noncompliant items can be flagged with an asterisk or displayed double bright. Figure 7-14 is a sample checklist.

7.4.4.2.4 Performance Evaluation. The performance evaluation scores parameters on a percentage of time inside tolerance basis, obtaining the result by comparing the aircraft parameter values against prespecified standard values. The system also indicates any maximum excursions and provides a list of events, alongside which elapsed time from start of practice indicates when each occurred. The evaluation system is phase oriented, with the starting and ending of each phase being defined by up to three events. The practice can be activated with or without a setup. To enable easy selection by the user of performance evaluation parameters, it is suggested that a facility be provided to enable customer construction of performance evaluation pages.

Table 7-12 and Figures 7-15 and 7-16 describe the components of a basic performance evaluation edit/create system. Figure 7-17 shows a typical performance evaluation page.

This evaluation system is oriented towards IFR and VFR procedures. With respect to the AH-64, the following parameters could be scored during instrument flight:

. Airspeed

. Altitude

. Heading

. Vertical speed

. ADF bearing

Application of the evaluation system to VFR point-to-point procedures could include the scoring of the following parameters:

. Height above ground

. Low level contour

. Nap of the earth (NOE)

. Deviation from specified track

. Time over specified points

. Time unmasked

PAGE 50 BEFORE TAKE-OFF CHECKLIST

| | | |
|---|---|---|
| | ENG, TRANS, HYD INDICATORS | - GREEN RANGE |
| | MASTER CAUTIO.. PANEL | - LIGHTS EXTINGUISHED |
| | FUEL BOOST PUMPS | - ALL ON |
| | GENERATORS | - PARALLELED |
| | UHF RECVR | - T/R AND G |
| * | ANTI COLLISION LTS | - ON |
| | PITOT HEAT | - ON |
| | SAS | - ON |
| | TRANSPONDER | - ON |
| | MASTER ARMAMENT SW | - OFF |
| | ANTI-ICING | - AS REQ'D |

NOTE: NONCOMPLIANT ITEMS FLAGGED *

A/C CONDITIONS

LOADING

| | |
|---|---|
| GROSS WEIGHT | CG |
| 15200 | 201 |
| FUEL | EXT FUEL |
| 1500 | 0 |

AMBIENTS

| | |
|---|---|
| OAT | QNH |
| 12 | 1013.2 |
| WIND DIR | WIND VEL |
| 071 | 5 |

POSITION

| | |
|---|---|
| LAT | LONG |
| 32:44:12 | 045:40:00 |

FLIGHT

| | |
|---|---|
| IAS | HDG |
| 85 | 149 |
| ALT | RALT |
| 1676 | 890 |

COMMUNICATIONS

| | | |
|---|---|---|
| VHF FM | VHF AM | UHF AM |
| 30.00 | 116.025 | 255.500 |

ACTIVE MALFUNCTIONS

1 PILOT'S RMI FROZEN
2 SAS FAIL
3
4.
5
6
7
8
9
10

CREW NAME: SMITH, JONES

MISSION TIME ØØ:ØØ:ØØ

| MSL | | | RKT | | | | | GUN | RKT | | | | | MSL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF/IR | LSR | TV | FLGHT | MKR | HE435 | HE429 | PD17 | | FLGHT | MKR | HE435 | HE429 | PD17 | RF/IR | LSR | TV |
| 0 | 4 | 0 | 6 | 3 | 1 | 3 | 6 | 626 | 6 | 3 | 1 | 3 | 6 | 0 | 4 | 0 |

Figure 7-14. Checklist Verification

PAGE 99 PERFORMANCE EVALUATION EDIT/CREATE

| | | |
|---|---|---|
| 1 | MANEUVER NUMBER 1 TO 15) | 3 |
| 2 | DESTROY PRESENT FILE | |
| 3 | NUMBER OF PHASES (1 TO 5) | 4 |
| 4 | EVENT NUMBER (1 TO 10) | 1 |
| 5 | SCORE (1 TO 8) | |
| 6 | PHASE STARTING (+/-1 TO +/-3) | |
| 7 | ENDING | |
| 8 | PARAMETER (1 TO 15) | 1 |
| 9 | EVENT COMMENT (1 TO 15) | 3 |
| 10 | MEAN VALUE | 90 |
| 11 | PLUS TOLERANCE | |
| 12 | MINUS | |
| 13 | INCREASING THROUGH | YES |
| 14 | DECREASING | |
| 15 | ON STATE | |
| 16 | OFF | |
| 17 | MONITOR/SCORE IN PHASE(S) | 123 |
| 18 | FILE | |

A/C CONDITIONS

LOADING

| | |
|---|---|
| GROSS WEIGHT 15200 | CG 201 |
| FUEL 1500 | EXT FUEL 0 |

AMBIENTS

| | |
|---|---|
| OAT 12 | QNH 1013.2 |
| WIND DIR 071 | WIND VEL 5 |

POSITION

| | |
|---|---|
| LAT 32:44:12 | LONG 045:40:00 |

FLIGHT

| | |
|---|---|
| IAS 85 | HDG 149 |
| ALT 1676 | RALT 890 |

COMMUNICATIONS

| | | |
|---|---|---|
| VHF FM | VHF AM | UHF AM |
| 30.00 | 116.025 | 255.500 |

ACTIVE MALFUNCTIONS

1 PILOT'S RMI FROZEN
2 SAS FAIL
3
4
5
6
7
8
9
10

CREW NAME: SMITH, JONES

MISSION TIME 00:00:00

| MSL | | | RKT | | | | | GUN | RKT | | | | | MSL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF/IR | LSR | TV | FLCHT | MKR | HE435 | HE429 | PD17 | | FLCHT | MKR | HE435 | HE429 | PD17 | RF/IR | LSR | TV |
| 0 | 4 | 0 | 6 | 3 | 1 | 3 | 6 | 626 | 6 | 3 | 1 | 3 | 6 | 0 | 4 | 0 |

Figure 7-15. Performance Evaluation Edit/Create Page

TABLE 7-12. EDIT/CREATE LINE CONTROLS

| PERFORMANCE EVALUATION EDIT/CREATE PAGE. | |
|---|---|
| LINE 1 | To edit or create a PACE exercise, enter appropriate maneuver number; all volatile fields will display blanks. |
| 2 | If an exercise changes drastically, it may be desired to destroy the old definition. |
| 3 | If an exercise already exists, the total number of phases in this maneuver will be displayed; otherwise, the field will be blank. The number of phases may be changed through this line. |
| 4 | If a monitored event is to be defined or edited, enter the event number here. This number represents the order in which the event times and comments appear on the actual evaluation page. When this event already exists, the data previously specified for this event will appear on lines 8 through 17; otherwise, those lines will remain blank. |
| 5 | Similar to 4, this number specifies the order in which the scored parameter names appear on the actual evaluation page. |
| 6,7 | If a phase starting or ending event is to be defined, enter the number of one of the three possible subevents here. Positive entry means ANDing of events, negative implies ORing. See 4 or 5. |
| 8 | This entry specifies which parameter to monitor. Selection is made from Figure 7-15. |
| 9 | This entry specifies which comment string to display on evaluation page. Selection is made from Figure 7-15. |
| 10 | This entry specifies the value the parameter must achieve, or the station index number for station passage, or standard value for scored parameter. |
| 11,12 | Plus, minus tolerance may be specified for events when applicable. |
| 13,14 | For monitored and phase events, these entries specify how the parameter is tested. If neither of these lines is selected, the event will be satisfied when the parameter increases <u>or</u> decreases through the mean value. |
| 15,16 | Some events are of the Boolean (ON or OFF) variety. These entries specify a test for the ON state of the parameter or for the OFF state. ON and OFF states are defined in the parameters list (Figure 7-16). |
| 17 | This entry specifies in which phase to monitor the associated event. |
| 18 | Selection of this line ends the editing or creation of the particular event, establishing it as part of the evaluation system. |

PAGE 100 PERFORMANCE EVALUATION MENU

| | PARAMETER | UNITS |
|---|---|---|
| 1 | A/S | KTS |
| 2 | V/S | FT/MIN |
| 3 | ALT | FT |
| 4 | PITCH | DEG |
| 5 | HDG | DEG |
| 6 | ADF BRG | DEG |
| 7 | VOR BRG | DEG |
| 8 | GS DEV | DOTS |
| 9 | LOC DEV | DOTS |
| 10 | TIMING | SECS |
| 11 | TIME DLY | SECS |
| 12 | MRKR SW | HI=ON |
| 13 | LDG GEAR | DWN=ON |
| 14 | STN INDEX | |
| 15 | SPARE | |

EVENT COMMENTS

1 LDG GEAR DOWN
2 MRKR HI TO LO
3 MISSED APPR
4 NON-POS CLIMB
5 COMM PROC TURN
6 COMM 180 TURN
7 REACHING MDA
8 OUTER MARKER
9 MIDDLE MARKER
10 HIGH CONE
11 LO CONE
12 OVER (STATION IDENT)
13 HEADING (SELECTED MEAN)
14 AIRSPEED (SELECTED MEAN)
15 ALT (SELECTED MEAN)

A/C CONDITIONS

LOADING

| GROSS WEIGHT | CG |
|---|---|
| 15200 | 201 |
| FUEL | EXT FUEL |
| 1500 | 0 |

AMBIENTS

| OAT | QNH |
|---|---|
| 12 | 1013.2 |
| WIND DIR | WIND VEL |
| 071 | 5 |

POSITION

| LAT | LONG |
|---|---|
| 32:44:12 | 045:40:00 |

FLIGHT

| IAS | HDG |
|---|---|
| 85 | 149 |
| ALT | RALT |
| 1676 | 890 |

COMMUNICATIONS

| VHF FM | VHF AM | UHF AM |
|---|---|---|
| 30.00 | 116.025 | 255.500 |

ACTIVE MALFUNCTIONS

1 PILOT'S RMI FROZEN
2 SAS FAIL
3
4
5
6
7
8
9
10

CREW NAME: SMITH, JONES

MISSION TIME 00:00:00

| MSL | | | RKT | | | | | GUN | RKT | | | | | MSL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF/IR | LSR | TV | FLCHT | MKR | HE435 | HE429 | PD17 | | FLCHT | MKR | HE435 | HE429 | PD17 | RF/IR | LSR | TV |
| 0 | 4 | 0 | 6 | 3 | 1 | 3 | 6 | 626 | 6 | 3 | 1 | 3 | 6 | 0 | 4 | 0 |

Figure 7-16. Performance Evaluation Menu Page

PAGE 101 HOLDING ENTRY DIRECT

1 PRACTICE WITH SETUP
2 PRACTICE WITHOUT SETUP

| PHASE | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| IAS | 80% | 90% | 90% | 100% |
| V/S | | | 79% | |
| ALT | 100% | 100% | | |
| ADF BRG | | 91% | 90% | |

EVENTS

| | |
|---|---|
| 02:16 | MRKR HI TO LO |
| | NON-POS CLIMB |
| 03:24 | COMM PROC TURN |
| 09:00 | MIDDLE MARKER |

SCORE GOOD

A/C CONDITIONS

LOADING

| | |
|---|---|
| GROSS WEIGHT 15200 | CG 201 |
| FUEL 1500 | EXT FUEL 0 |

AMBIENTS

| | |
|---|---|
| OAT 12 | QNH 1013.2 |
| WIND DIR 071 | WIND VEL 5 |

POSITION

| | |
|---|---|
| LAT 32:44:12 | LONG 045:40:00 |

FLIGHT

| | |
|---|---|
| IAS 85 | HDG 149 |
| ALT 1676 | RALT 890 |

COMMUNICATIONS

| VHF FM | VHF AM | UHF AM |
|---|---|---|
| 30.00 | 116.025 | 255.500 |

ACTIVE MALFUNCTIONS

1 PILOT'S RMI FROZEN
2 SAS FAIL
3
4
5
6
7
8
9
10

CREW NAME: SMITH, JONES

MISSION TIME 00:00:00

| MSL | | | RKT | | | | | GUN | RKT | | | | | MSL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF/IR | LSR | TV | FLCHT | MKR | HE435 | HE429 | PD17 | | FLCHT | MKR | HE435 | HE429 | PD17 | RF/IR | LSR | TV |
| 0 | 4 | 0 | 6 | 3 | 1 | 3 | 6 | 626 | 6 | 3 | 1 | 3 | 6 | 0 | 4 | 0 |

Figure 7-17. Performance Evaluation

7.4.4.2.5 Tactical Mission Evaluation. One area not subjected to automatic evaluation techniques thus far is the tactical mission. Many evaluation systems tend toward compromise in which the typical outcome is to measure that which can be measured rather than that which should be measured. The first objective then will be to define what should be measured during a tactical mission and how it should be measured.

The main objectives during a tactical mission are:

. Destroy threat forces

. Survive

How these two objectives are achieved is not as important as the requirement that they be achieved. The evaluation can then be approached in two directions.

The following parameters could provide a measure of the effectiveness of the crew to obtain the objective of destroying enemy armor:

. Time to locate target

. Time to identify target

. Time to immobilize target

. Time to destroy target

. Weapons expended to destroy target

. Weapons expended to immobilize target

Obviously, the faster a target is located, identified, and destroyed with minimum weapons expended, the higher should the performance be graded.

The following parameters could provide a measure of the ability of the crew to survive:

. Time exposed

. Time under fire

. Sequence of attack (e.g., anti-aircraft vehicles first)

. Deviation from optimum course

An exact formula tying both objectives together and yielding a meaningful grade that can be reliably used as a yardstick for crew against crew comparison has not been determined, nor is it known whether it is required. This and the method of presenting running score reports are areas that should be considered for further study.

7.4.4.3 Lesson Plan System

7.4.4.3.1 General. The purpose of the lesson plan system is to present the instructor with a chart of events that is related to a specific training mission and that allows him to control the progress of the mission with the least possible effort. The instructor can then devote more time to observation and correction of the trainee.

Using a lesson plan system, lesson steps are executed as established by the training authorities. This ensures consistent training in that all trainees are subjected, as nearly as possible, to the same mission conditions. Trainee evaluation on a comparison basis then becomes meaningful.

The lesson plan system should be easy to operate and provide the capability of easily creating changing lessons, possibly using a compiler. The lesson plan system should be able to execute all functions normally accessible through the instructor facility. A suggested design for such a lesson plan is described in the subsequent paragraphs.

7.4.4.3.2 Lesson Plan System Design. The lesson plan system suggested provides the instructor with single pushbutton control over the entire training situation. The lesson is generated by using a compiler and is composed of a series of steps, each of which, when activated, can perform up to 10 discrete functions. Activation of a lesson plan step can be instructor selected or automatic when a specific stage of the training exercise is detected. Each lesson is presented to the instructor on a CRT page that can be scrolled up or down a step at a time, since all steps in a lesson may not fit on the screen at one time.

Lesson plans may be created through operation of the lesson plan compiler utility. The utility uses a lesson plan menu (Table 7-13) containing all the functions that are normally available to the instructor through the instructor console and CRT page system; thus a step can reduce an instructor's series of activities into one action, i.e., depressing LESSON PLAN INSERT.

The compiler, using the menu as a reference, uses plain language prompts and responses (Table 7-14) to create a new lesson plan (Table 7-15 and 7-16) or to edit an existing lesson plan (Table 7-17 and 7-18). The compiler also contains the capability of listing and destroying lesson plans.

Comments may comprise a lesson step alone, the objective being to have the instructor acknowledge the steps assigned to him. The provision to mark lesson steps, using color or a margin symbol, as applicable to PILOT or CPG (or both) exists.

A single pushbutton (LESSON PLAN INSERT) is used for lesson step activation by the instructor. A margin symbol or color indicates the next step to be executed (step of interest), and after execution the indicator automatically moves to the next step.

TABLE 7-13. LESSON PLAN COMPILER MENU

| | |
|---|---|
| **LOADING** | |
| 1 | SET GW |
| 2 | SET CG |
| 3 | SET ZERO FUEL WEIGHT |
| 4 | SET TOTAL FUEL |
| 5 | SET FORWARD FUEL |
| 6 | SET AFT FUEL |
| **WING STORES/ARMAMENT** | |
| 20 | SET MSL RO RF/IR |
| 21 | SET MSL RO LASER |
| 22 | SET MSL RO TV |
| 23 | SET RCKT RO FLCHT |
| 24 | SET RCKT RO MKR |
| 25 | SET RCKT RO HE435 |
| 26 | SET RCKT RO HE429 |
| 27 | SET RCKT RO PD17 |
| 28 | SET FUEL TANK RO |
| 30 | SET MSL RI RF/IR |
| 31 | SET MSL RI LASER |
| 32 | SET MSL RI TV |
| 33 | SET RCKT RI FLCHT |
| 34 | SET RCKT RI MKR |
| 35 | SET RCKT RI HE435 |
| 36 | SET RCKT RI HE429 |
| 37 | SET RCKT RI PD17 |
| 38 | SET FUEL TANK RI |
| 40 | SET MSL LO RF/IR |
| 41 | SET MSL LO LASER |
| 42 | SET MSL LO TV |
| 43 | SET RCKT LO FLCHT |
| 44 | SET RCKT LO MKR |
| 45 | SET RCKT LO HE435 |
| 46 | SET RCKT LO HE429 |
| 47 | SET RCKT LO PD17 |
| 48 | SET FUEL TANK LO |
| 50 | SET MSL LI RF/IR |
| 51 | SET MSL LI LASER |
| 52 | SET MSL LI TV |
| 53 | SET RCKT LI FLCHT |
| 54 | SET RCKT LI MKR |
| 55 | SET RCKT LI HE435 |
| 56 | SET RCKT LI HE429 |
| 57 | SET RCKT LI PD17 |
| 58 | SET FUEL TANK LI |
| 60 | SET GUN ROUNDS |

TABLE 7-13 LESSON PLAN COMPILER MENU (Continued)

ENVIRONMENT

| | |
|---|---|
| 100 | SET SURFACE TEMPERATURE |
| 101 | SET TEMP LAPSE RATE |
| 102 | SET QNH |
| 103 | SET SURFACE WIND DIRECTION |
| 104 | SET SURFACE WIND SPEED |
| 105 | SET WIND DIRECTION LAPSE RATE |
| 106 | SET WIND VELOCITY LAPSE RATE |
| 107 | SET TURBULENCE LEVEL |
| 108 | SET ICING RATE |
| 109 | SET ICING TYPE |
| 110 | SET RUNWAY ROUGHNESS |
| 111 | SET RUNWAY ICE |
| 112 | SET RUNWAY SLUSH |
| 113 | SET RUNWAY RAIN |
| 114 | SET SHEAR PROFILE |
| 115 | SET RAIN |
| 116 | SET HAIL |

MISCELLANEOUS

| | |
|---|---|
| 200 | EXTERNAL AC PWR |
| 201 | EXTERNAL HYDRAULICS |
| 202 | ALL QUANTITIES NORMAL |
| 203 | REFILL FIRE BOTTLES |
| 204 | ENGINE FAST START |
| 205 | RECHARGE BATTERY |
| 206 | SET ALTITUDE |
| 207 | FREEZE ALTITUDE |
| 208 | SET AIRSPEED |
| 209 | FREEZE AIRSPEED |
| 210 | SET HEADING |
| 211 | FREEZE HEADING |

POSITION & MAPPING

| | |
|---|---|
| 300 | REPOSITION TO STN NO. |
| 301 | SET ILS REFERENCE POSITION |
| 302 | SET MAP CENTER |
| 303 | SET MAP SCALE |
| 304 | DISPLAY MAP |
| 305 | RANGE MARKER |
| 306 | KILL STN NO. |
| 307 | RESET STN NO. |
| 308 | GENERAL STN RESET |
| 309 | ADVANCE ON TRACK |
| 310 | SET LATITUDE |
| 311 | SET LONGITUDE |

TABLE 7-13 LESSON PLAN COMPILER MENU (Continued)

VISUAL

| | |
|---|---|
| 400 | APPROACH LIGHTS INTENSITY |
| 401 | RUNWAY LIGHTS INTENSITY |
| 402 | VASI |
| 403 | SCUD |
| 404 | VISUAL STN REFERENCE NO. |
| 405 | VISUAL ENVIRONMENT NO. |
| 406 | APPROACH STROBE LIGHTS |
| 407 | SET CLOUD BASE |
| 408 | SET CLOUD TOPS |
| 409 | SET VISIBILITY (RVR) |

I/F FUNCTIONS

| | |
|---|---|
| 500 | DISPLAY ANVIL PAGE NO. |
| 501 | HARDCOPY ANVIL PAGE NO. |
| 502 | HARDCOPY MAP |
| 503 | TIME HISTORY PLOT |
| 504 | PLAY AUDIO CHANNEL NO. |
| 505 | DEMONSTRATE MANEUVER NO. |
| 506 | EVALUATE MANEUVER NO. |
| 507 | ACTIVATE UNUSUAL ALTITUDE |
| 508 | CALL SETUP NO. |
| 509 | CALL SCENARIO NO. |

MALFUNCTIONS

| | |
|---|---|
| 600 | ACTIVATE DISCRETE MALF NO. |
| 601 | ACTIVATE VARIABLE MALF AT RATE |

OTHERS

| | |
|---|---|
| 900 | TEXT SPECIFICATION |

TABLE 7-14 LESSON PLAN COMPILER PROMPTS AND RESPONSES

| PROMPT | USER INPUT | DESCRIPTION |
|---|---|---|
| **Common to all modes** | | |
| MODE (C,E,D,L) : | C | To create a new lesson. |
| | E | To edit a lesson. |
| | D | To destroy a lesson. |
| | L | To list lesson page on handcopy device. |
| ENTER LP NUMBER : | (1 to 50) | Enter number of the lesson to be created, edited, destroyed, or listed. |
| TITLE : | (0 to 32 characters) | Specify title of lesson plan (if desired) when creating or editing. |
| QUIT ? | Y (N ) | Requires user to confirm intent of previous request. Y response necessary to successfully terminate session. |
| **Create Mode** | | |
| STEP 1 : | code, desired value | To set a variable to a specific value. Comment appears as in menu. |
| and/or | code, desired value, (0 to 32 characters) | Comment as in menu is preempted by specified characters. |
| and/or | code, ON (OFF) | To set a Boolean function on or off. |
| and/or | code, ON (OFF), (0 to 32 characters) | |
| and/or | 900, (0 to 32 characters) | Code 900 allows specification of comment only information. |
| | Carriage return | To end creation of present step. |

TABLE 7-14 LESSON PLAN COMPILER PROMPTS AND RESPONSES (Continued)

| PROMPT | USER INPUT | DESCRIPTION |
|---|---|---|
| **Edit mode** | | |
| STEP ? | step number | Enter next step to be edited. If this number does not exist system assumes a new step is to be inserted. |
| | | To end edit session. |
| STEP 1 : | R, code,desired value | Add a new item to step. Format as for create mode. |
| | | If new step, inputs as per create mode. |
| | Carriage Return | To end edit of present step. |

TABLE 7-15 TO CREATF A NEW LESSON PLAN

Call lesson plan compiler, then

| PROMPT | USER LIMIT | COMMENTS |
|---|---|---|
| MODE (C,E,D,L) : | C | Create new lesson number 5. If LP 5 already existed, entry would be rejected and prompt repeated. |
| ENTER LP NUMBER : | 5 | |
| TITLE : | NOE-REDUCED VISIBILITY | Now follow step definitions. |
| STEP 1 : | 900, SET UP A/C CONFIGURATION | Comment |
| | 1,28000 | GW - 28000 |
| | 2,27. | CG - 27.1 |
| | 4,4000 | FUEL - 4000 |
| | 302,155 | Map Center - 155 |
| | 303,2 | MAP Scale - 2 |
| | Carriage return | End step definition. Now define next step. |
| STEP 2 : | 900, SET UP AMBIENT CONDITIONS | Comment |
| | 100,15 | Surf temperature - 15 |
| | 102, 1013.2 | ONH - 1013.2 |
| | 104,10 | Surf wind velocity - 10 |
| | 106,3 | Wind vel lapse rate - 3 |
| | 103,260 | Surf wind direction - 260 |
| | 105,2 | Wind dir lapse rate - 2 |
| | Carriage return | End step definition. |
| STEP 3 : | | To terminate lesson create |
| QUIT ? | Y | Confidence |

TABLE 7-16. NEW LESSON PLAN

| | | |
|---|---|---|
| LESSON 5 | NOE-REDUCED VISIBILITY | |
| | 1 - SET UP A/C CONFIGURATION | |
| | SET GW - 28000 | SET CG - 27.1 |
| | SET TOTAL FUEL - 4000 | SET MAP CENTER - 155 |
| | SET MAP SCALE - 2 | |
| | 2 - SET UP AMBIENT CONDITIONS | |
| | SET SURF TEMP - 15 | SET QNH - 1013.2 |
| | SET SURF WIND VEL - 10 | SET WIND VEL LAPSE RATE - 3 |
| | SET SURF WIND DIRECTION - 260 | SET WIND DIR LAPSE RATE - 2 |
| | END OF LESSON | |

TABLE 7-17. TO EDIT A LESSON PLAN

Call lesson plan compiler, then

| PROMPT | USER INPUT | COMMENTS |
|---|---|---|
| MODE (C,E,D,L) : | | Edit existing lesson number 5. |
| ENTER LP NUMBER : | E | |
| TITLE : | 5 | No change in title; otherwise enter new title. |
| STEP ? | | Enter step number to be changed. |
| | 1 | Now enter changes. |
| STEP 1 : | R,4,3800 | Replace fuel - 4000 with - 3800 |
| STEP 1 : | A,304,ON | Add display map. |
| STEP 1 : | | All changes to step 1 complete. Now able to edit another step. |
| STEP ? | 2.1 | Insert a step after step 2. |
| STEP 2.1 : | 900, **PERFORM PREFLIGHT CHECKS | Comment |
| STEP 2.1 : | | |
| STEP ? | | No more changes to make |
| QUIT | | Confidence |
| | Y | |

TABLE 7-18. NEW LESSON PLAN AFTER EDIT

| | | |
|---|---|---|
| LESSON 5 | NOE-REDUCED VISIBILITY | |
| 1 - | SET UP A/C CONFIGURATION | SET CG - 27.1 |
| | SET GW - 28000 | SET MAP CENTER - 155 |
| | SET TOTAL FUEL - 3800 | DISPLAY MAP |
| 2 - | SET UP AMBIENT CONDITIONS | |
| | SET SURF TEMP - 15 | SET QNH - 1013.2 |
| | SET SURF WIND VEL - 10 | SET WIND VEL LAPSE RATE - 3 |
| | SET SURF WIND DIRECTION - 260 | SET WIND DIR LAPSE RATE - 2 |
| 3 - | **PERFORM PREFLIGHT CHECKS | |
| | END OF LESSON | |

Progression through the lesson plan is indicated by a permanent change to any completed action or comment line (color or margin symbol). Controls for skipping over lesson steps are provided (SKIP UP, SKIP DOWN), as well as for scrolling the lesson page up or down (SCROLL UP, SCROLL DOWN). All lesson plan controls are functional even with the lesson plan page out of view when in the lesson plan mode. Lesson plan controls are listed in Table 7-19 and illustrated in Figure 7-18.

TABLE 7-19. LESSON PLAN CONTROLS

| PUSHBUTTON | FUNCTION |
|---|---|
| INSERT | Causes step of interest to be executed when in lesson mode. |
| SKIP UP, SKIP DOWN | Causes step of interest to move up/down one step. |
| SCROLL UP, SCROLL DOWN | Scroll lesson page up/down a step at a time continuously while button is depressed. |

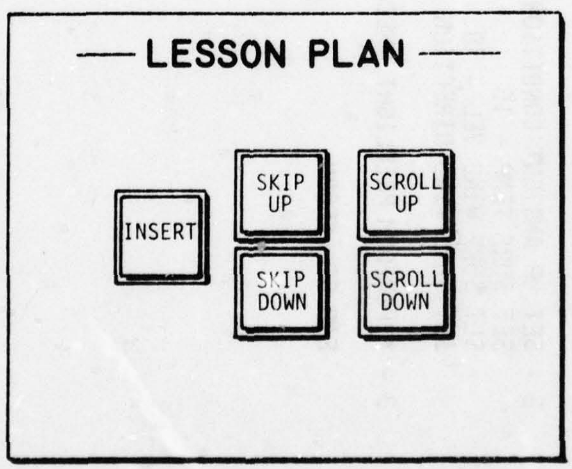



Figure 7-18. Lesson Plan Controls

7.4.4.4 Tactical Situation Control. The capability of defining threat and friendly force configurations in position, speed, direction, and type is a necessity for the AH-64 simulator. Such a facility can be entirely automated and allowed to run throughout a training mission, but a manual mode is required to allow the instructor the flexibility to vary conditions, depending on a trainee's progress.

Initialization of the complete battlefield hardware to prespecified configurations using a CRT control page line entry or a lesson plan step, can be attained by using a scenario management feature. The following information could be specified for threat and friendly forces:

- Initial X,Y,Z coordinates
- Initial heading
- Initial velocity
- ECM class (jamming ON/OFF)
- Vulnerability class
- Shoot-back class
- Shoot-back signature type

The instructor should have on-line control of the following:

- Heading
- Velocity
- ECM class
- Shoot-back (MANUAL/AUTO)

Figure 7-19 shows the scenario configuration control page. Through this page a configuration of threat and friendly forces can be defined, and, once defined, can be activated using the configuration number. Summaries of the configurations can appear on other CRT pages for easy reference, or, as a special feature, the configurations could be shown as an overview on the graphics display, similar to the contour area overview function. Table 7-20 shows the selection of threat vehicles, and a similar table would be used to show the selection of friendly venicles which could be included in a scenario configuration. Table 7-21 shows typical parameters that could be used to define threat vulnerability and shoot-back classes.

Realistic target movement is provided with a target control feature. The visual system, contour map scale, and a joystick are used to drive the target over the terrain. The visual shows the view outside the

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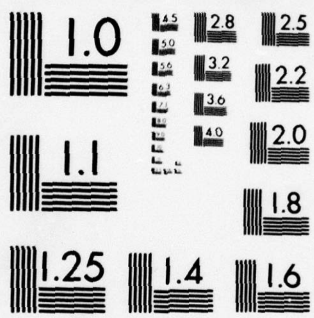

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

| | | | |
|---|---|---|---|
| PAGE 200 | | SCENARIO CONFIGURATION | |
| 1 | 1 | CONFIGURATION NUMBER | |
| 2 | 8 | TARGET NUMBER | |
| 3 | 7 | VEHICLE | |
| 4 | | CURSOR X,Y READ | |
| 5 | 237 | INITIAL | X COORDINATE |
| 6 | 85 | | Y |
| 7 | 0 | | Z |
| 8 | 220 | HEADING | |
| 9 | 10 | VELOCITY | |
| 10 | 2 | ECM CLASS | |
| 11 | 1 | VULNERABILITY CLASS | |
| 12 | 1 | SHOOT BACK CLASS | |
| 13 | 1 | SHOOT BACK SIGNATURE TYPE | |
| 14 | | FILE | |

**A/C CONDITIONS**

**LOADING**

| | |
|---|---|
| GROSS WEIGHT 15200 | CG 201 |
| FUEL 1500 | EXT FUEL 0 |

**AMBIENTS**

| | |
|---|---|
| OAT 12 | QNH 1013.2 |
| WIND DIR 071 | WIND VEL 5 |

**POSITION**

| | |
|---|---|
| LAT 32:44:12 | LONG 045:40:00 |

**FLIGHT**

| | |
|---|---|
| IAS 85 | HDG 149 |
| ALT 1676 | RALT 890 |

**COMMUNICATIONS**

| VHF FM | VHF AM | UHF AM |
|---|---|---|
| 30.00 | 116.025 | 255.500 |

**ACTIVE MALFUNCTIONS**

1 PILOT'S RMI FROZEN
2 SAS FAIL
3
4
5
6
7
8
9
10

CREW NAME: SMITH, JONES

MISSION TIME ØØ:ØØ:ØØ

| MSL | | | RKT | | | | GUN | RKT | | | | MSL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF/IR | LSR | TV | FLCHT | MKR | HE435 | HE429 | PD17 | FLCHT | MKR | HE435 | HE429 | PD17 | RF/IR | LSR | TV |
| 0 | 4 | 0 | 6 | 3 | 1 | 3 | 6 | 626 | 6 | 3 | 1 | 3 | 6 | 0 | 4 | 0 |

Figure 7-19. Scenario Configuration Page

## TABLE 7-20. VEHICLE TABLE

**ANTIAIRCRAFT MISSILES**

1 SA-2
2 SA-3
3 SA-4
4 SA-6

**ANTIAIRCRAFT GUNS**

5 ZSU-57-2
6 ZU-23-2
7 ZSU-23-4
8 ZPU-4
9 S-6Ø

**ANTIAIRCRAFT WEAPONS**

10 14.5mm
11 12.7mm
12 7.62mm
13 SA-7

**TANKS**

14 M48
15 T-55
16 M6ØA1
17 T-62
18 M6ØAs
19 T-1Ø

**COMBAT VEHICLES**

20 M551
21 ASU-57
22 ASU-25
23 BRDM
24 BMP

**ARTILLERY**

25 12Ømm
26 122mm HOWITZER
27 152mm
28 122mm ROCKETS

**AIRCRAFT**

29 SU-7
30 MIG-21
31 MIG-23
32 MIG-25
33 SU-11
34 HIP
35 HIND A

TABLE 7-21. VULNERABILITY AND SHOOT BACK CLASSES

THREAT VEHICLE VULNERABILITY CLASS DESCRIPTION

CLASS 1 (Typical)

| WEAPON | NO. HITS TO IMMOBILIZE | NO. HITS TO DESTROY |
|---|---|---|
| 2.75 | 20 | 30 |
| 30mm | N/A | N/A |
| HELLFIRE | 1 | 1 |
| TOW | 1 | 2 |

THREAT VEHICLE SHOOT BACK CLASS DESCRIPTION

CLASS 1 (Typical)

| PARAMETER | MIN | MAX | COMMENTS |
|---|---|---|---|
| TIME TO FIRE | 7 sec. | 18 sec. | (Timer starts at unmask and stops at mask) |
| FIRE TIME TO HIT | 0.5 sec. | 1 sec. | (Timer starts at comm. fire and stops at mask) |
| FIRE TIME TO DESTROY | 1 sec. | 2 sec. | (Timer starts at hit and ends at mask) |

Actual times programmed will vary, preferably in a random manner, between min. and max. specified.

front of the vehicle, while joystick fore/aft displacement controls the velocity and left/right displacement controls the heading. Once a target track has been defined, it may be replayed for validation. It is also possible to erase part of the track and redefine the vehicle path, starting at the erasure point. The advantage of this feature is that target movements are precisely controlled, eliminating the chance that a target would travel where, in real life, it could not normally go.

In general, battlefield hardware can be initialized by using pre-specified configurations activated through lesson steps, with on-line control of certain parameters available. The capability of inserting and deleting individual threat or friendly units at any time is also provided, but the former approach is recommended for the following reasons:

- Assurance of consistent training
- Fast scenario setup
- Reduction in specialized instructor training

### 7.4.5 Instructor/Operator Control Functions.

7.4.5.1 General. The interface between the instructor and the available instructor utilities is of great importance in a simulation environment. The controls at the instructor's fingertips must not be overly complex to operate since this would require too much operator time at the expense of instruction time. Also to be considered is the accessibility of controls; that is, the instructor should be able to reach them sitting in his normal seat position. This means that if a button control was provided for each function, a confusing mass of buttons would result. This necessitates a compromise by which the use of button combinations can be used to access facilities.

The philosophy behind the design of the instructor's panel is to provide quick access to frequently required functions, mostly via push-buttons. Both automated and manual modes are accommodated, and the design should conform to MIL-STD-1472B, where applicable.

At present, the suggested assembled panel configuration (Figure 7-20) is a general one for both pilot and copilot/gunner instructor stations. It is foreseen that this could change. The instructor panels will be flexible where additional information might be needed to support operation with one instructor managing the exercise from either flight compartment.

The suggested component panels are configured with a minimum number of functions, with control display functions immediately below and to the left of the monitor and the graphic display functions below that monitor.

A description of each subpanel is included in the following subparagraphs.

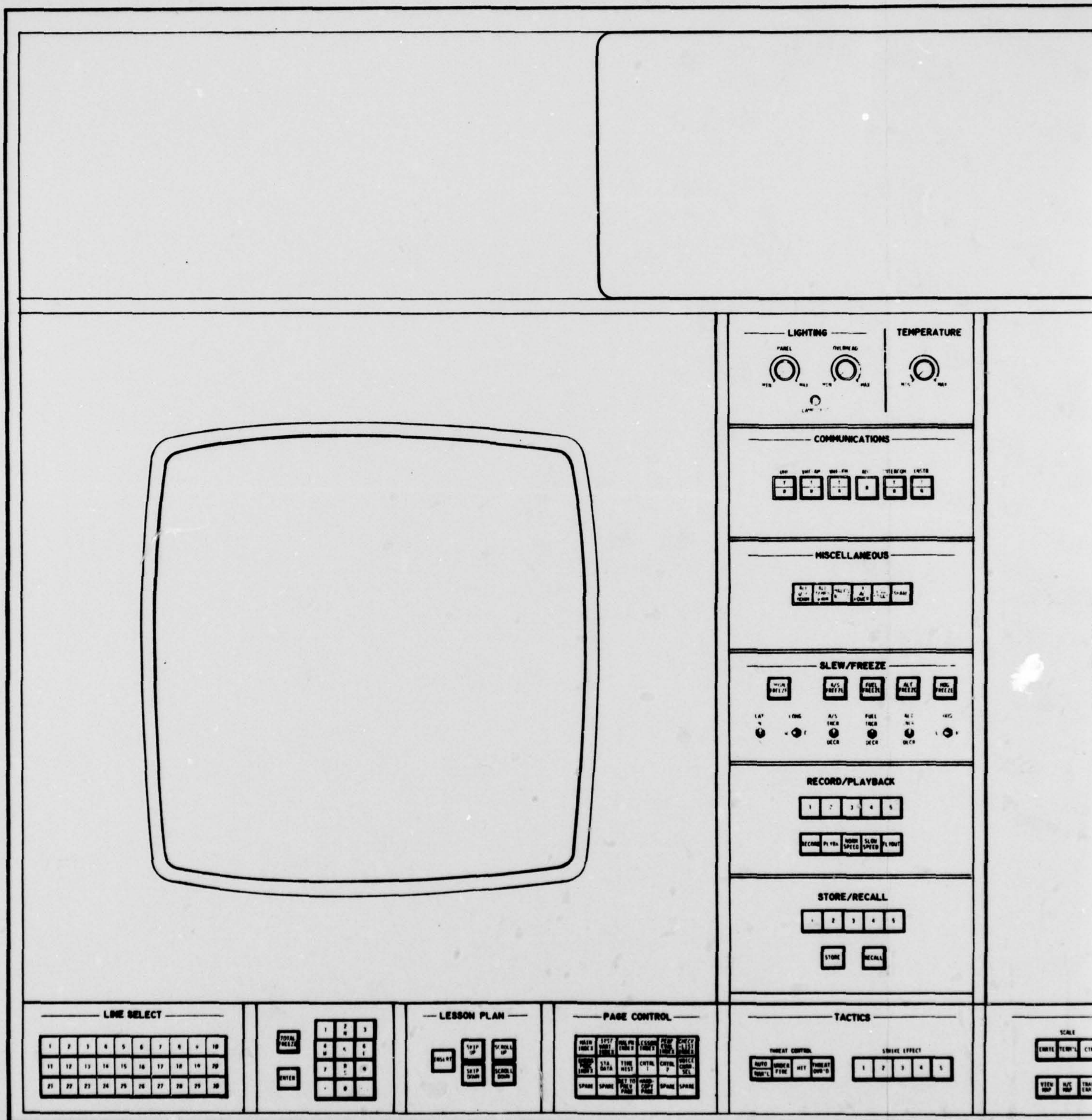
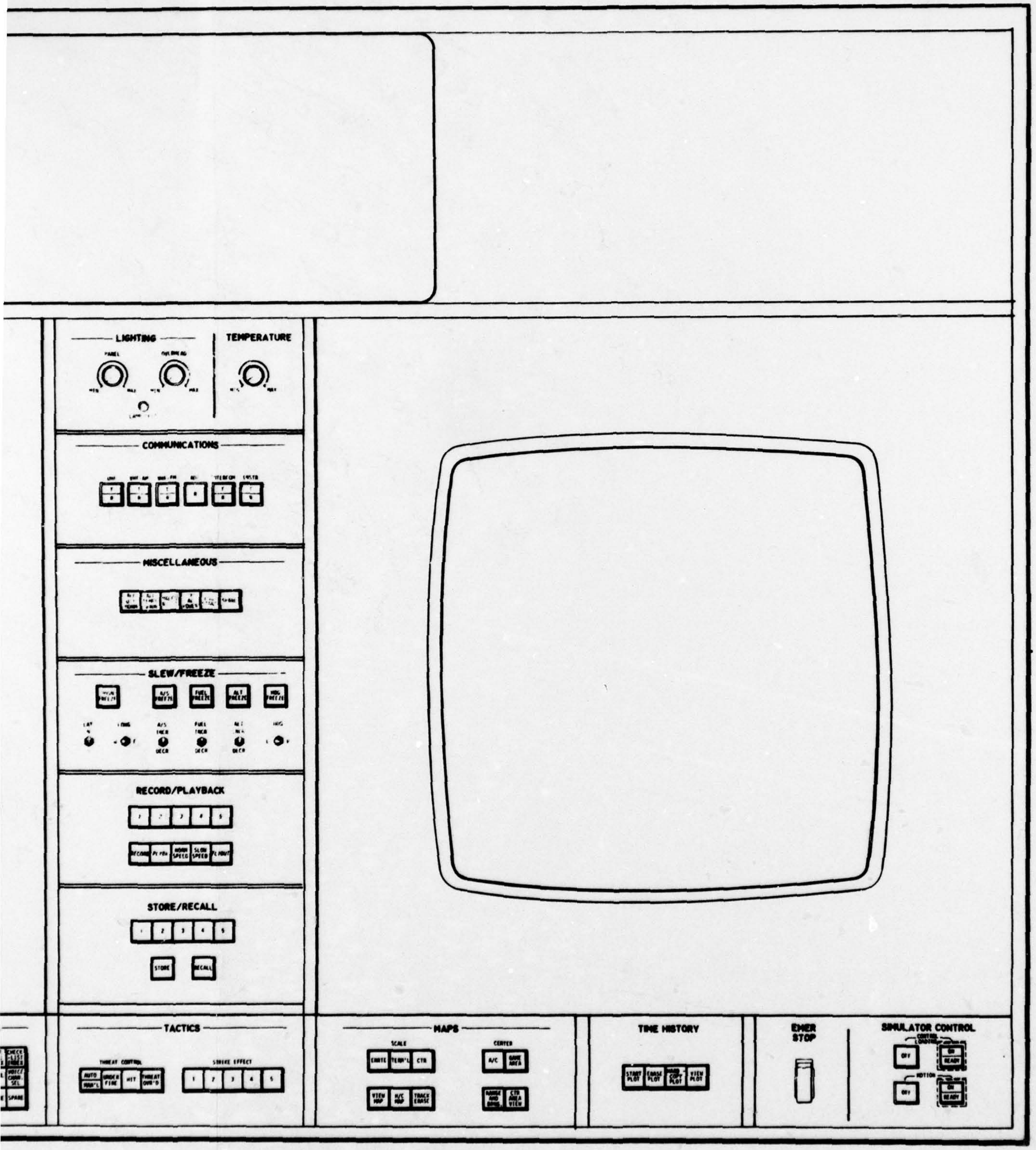



Figure 7-20 AH-64-FWS Instructor's Console Layout


LIGHTING
TEMPERATURE
COMMUNICATIONS
MISCELLANEOUS
SLEW/FREEZE
RECORD/PLAYBACK
STORE/RECALL
STORE
RECALL
TACTICS
THREAT CONTROL
STRIKE EFFECT
MAPS
SCALE
CENTER
TIME HISTORY
EMER STOP
SIMULATOR CONTROL

2

7.4.5.2 Direct Line Select Controls. Direct line select controls allow the instructor to select for input or to activate lines on the control display by depressing the corresponding line select pushbutton (Figure 7-21). If the selected line is not on the CRT page, no action is taken. If the line does exist on the CRT page, the line select button will flash, indicating that the line is armed and ready for input or will briefly change color (green to amber) and then return to normal (green) if the line represents a toggle-type function (OFF/ON).

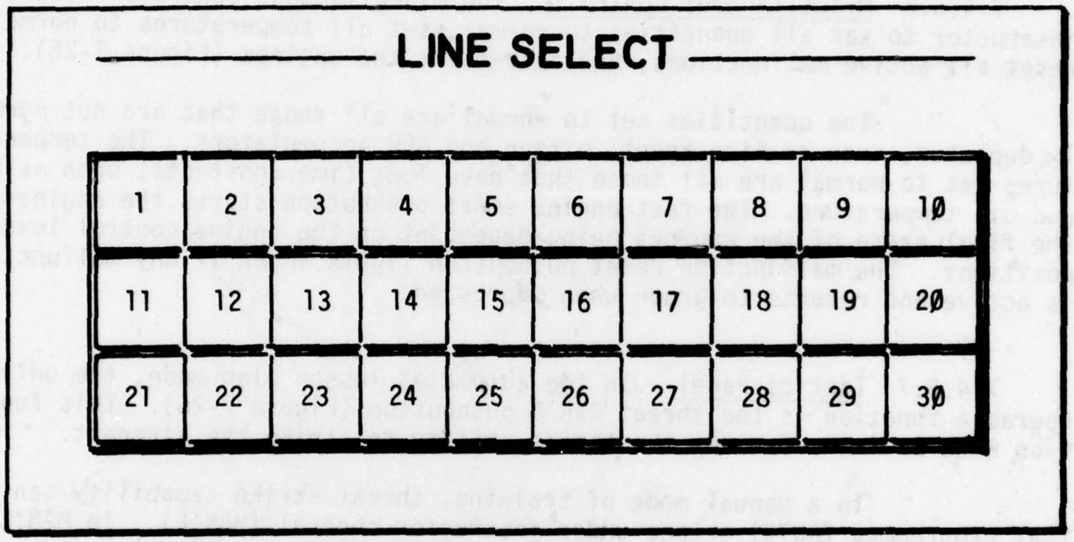



Figure 7-21. Direct Line Select Controls

7.4.5.3 Direct Page Select Controls. The direct page select controls allow the instructor to select a new CRT page on the control display by depressing the corresponding direct page select pushbutton (Figure 7-22). Normally green, the pushbutton is illuminated amber if it corresponds to the page in view. The index pages provide access to all the CRT pages by using direct line selections. Pushbuttons are provided for 'return to previous page' and hardcopy. The hardcopy pushbutton is illuminated amber while a hardcopy request is being serviced (less than two seconds). It reverts to green when no hardcopy is being produced.

7.4.5.4 Slew/Freeze Controls. The slew freeze controls allow the instructor to freeze or slew the aircraft position, airspeed, fuel load, altitude, and heading (Figure 7-23). Freeze is activated by depressing the appropriate pushbutton, the pushbutton color then changes from green to amber to indicate freeze on.

Parameter slew is implemented with three-position spring loaded switches. The center position is normal. The left/right or up/down positions activate the slew, the slew rate increasing with time.

7.4.5.5 Instructor's Keypack. The instructor's keypack allows the instructor to make numerical entries on selected CRT page lines and to activate/reset simulator total freeze (Figure 7-24). Normally green, freeze on is indicated when pushbutton is illuminated amber.

Once a line has been selected, input may be made by keying in the desired value, terminating the sequence with ENTER.

7.4.5.6 Miscellaneous Controls. The miscellaneous controls allow the instructor to set all quantities to normal, set all temperatures to normal, reset all active malfunctions, and fast-start the engines (Figure 7-25).

The quantities set to normal are all those that are not normally depleted, such as fire agent, oxygen and APU accumulators. The temperatures set to normal are all those that have long time constants, such as EGT and oil temperature. The fast engine start pushbutton starts the engines, the final state of the engines being dependent on the engine control lever positions. The malfunction reset pushbutton lights amber if any malfunction is active and reverts to green when depressed.

7.4.5.7 Tactics Panel. In the automated lesson plan mode, the only operable function is the threat OVR'D pushbutton (Figure 7-26). This function when active overrides the threat ability to strike the aircraft.

In a manual mode of training, threat strike capability can be that programmed (AUTO) or one under instructor control (MAN'L). In MAN'L, the UNDER FIRE indicator will flash when the aircraft is being engaged by a threat. As long as this indicator is flashing, the instructor may depress the HIT pushbutton, causing the aircraft to be struck, and the result on the aircraft is determined by the instructor's previous selection of one or more of the STRIKE EFFECT pushbuttons.

The STRIKE EFFECT pushbuttons allow the instructor to preset the effect of the next hit, whether it occurs with threat control in AUTO or MAN'L. A few examples of what a STRIKE EFFECT could be are listed below:

. Main rotor damage

. Tail rotor lost

. Crash

. Pilot unable to perform duties

7.4.5.8 Communications Controls. The communications controls allow the instructor to interchange voice communications with both crew members and the other instructor (Figure 7-27).

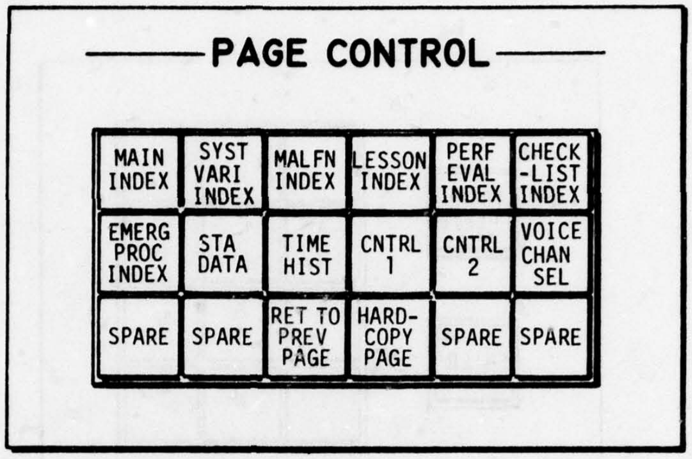



Figure 7-22. Direct Page Select Controls

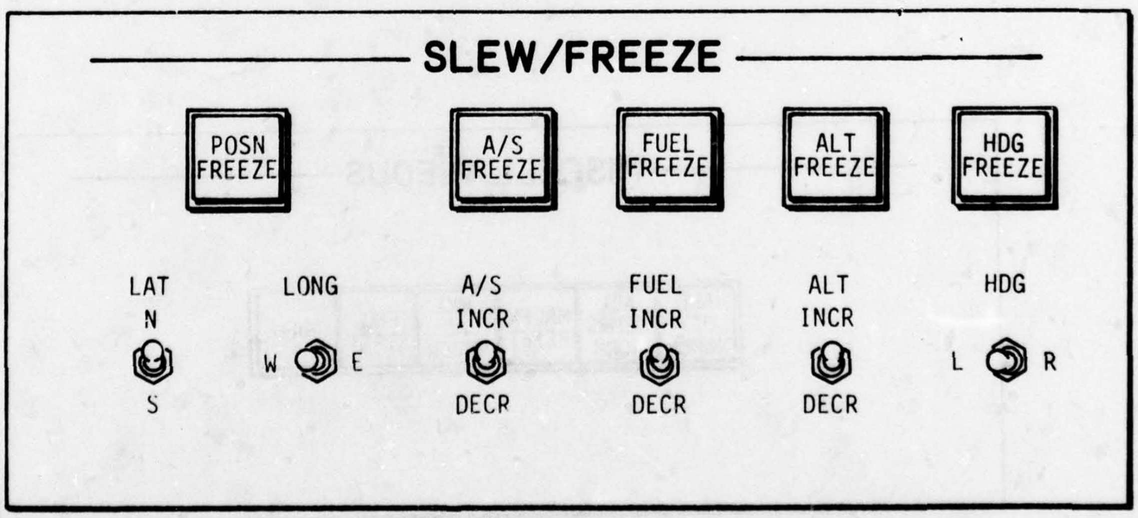



Figure 7-23. Slew/Freeze Controls

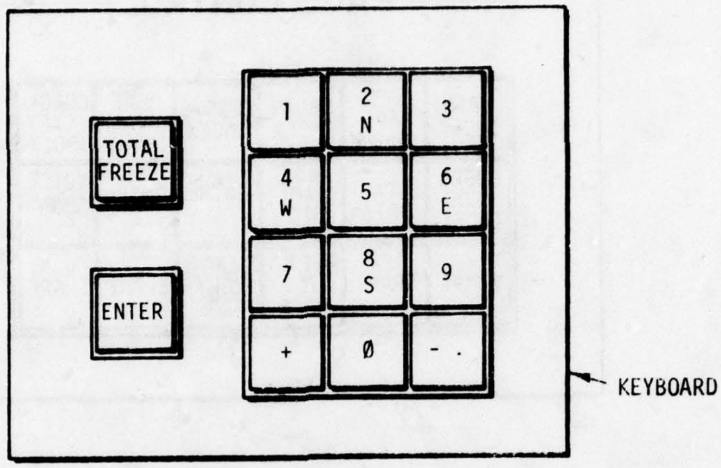



Figure 7-24. Instructor's Keypack

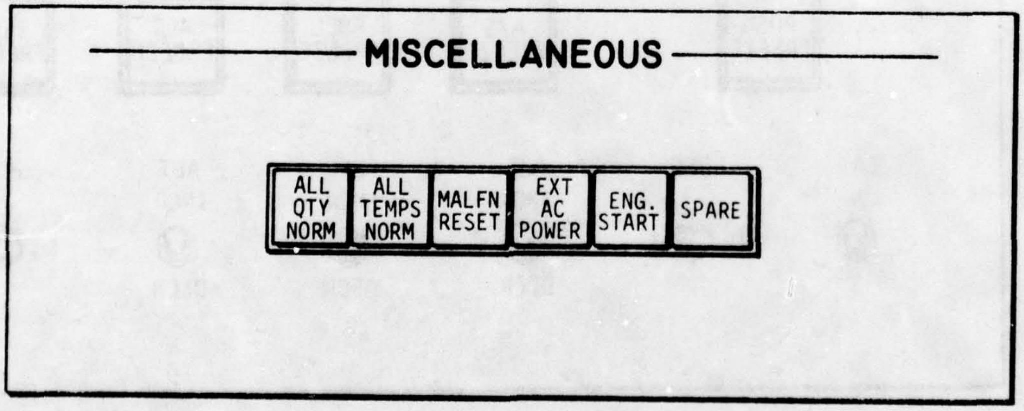



Figure 7-25. Miscellaneous Controls

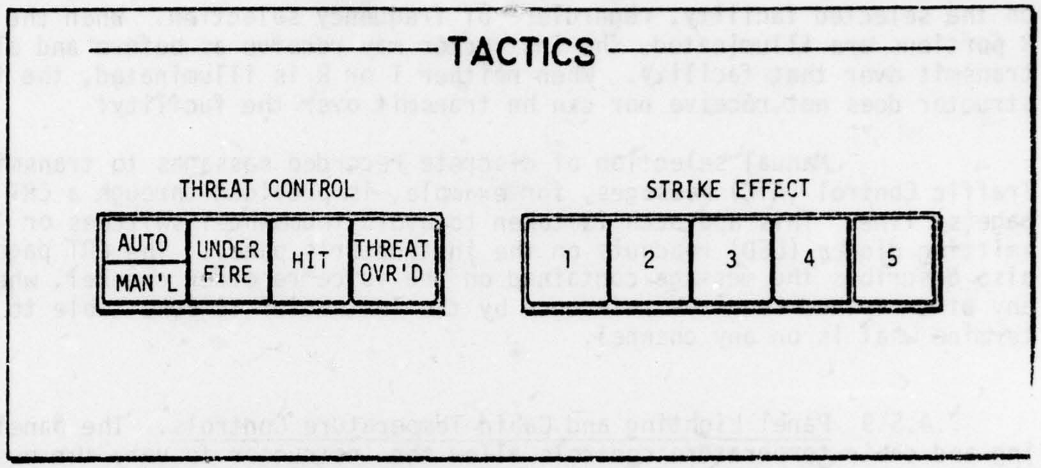



Figure 7-26. Tactics Panel

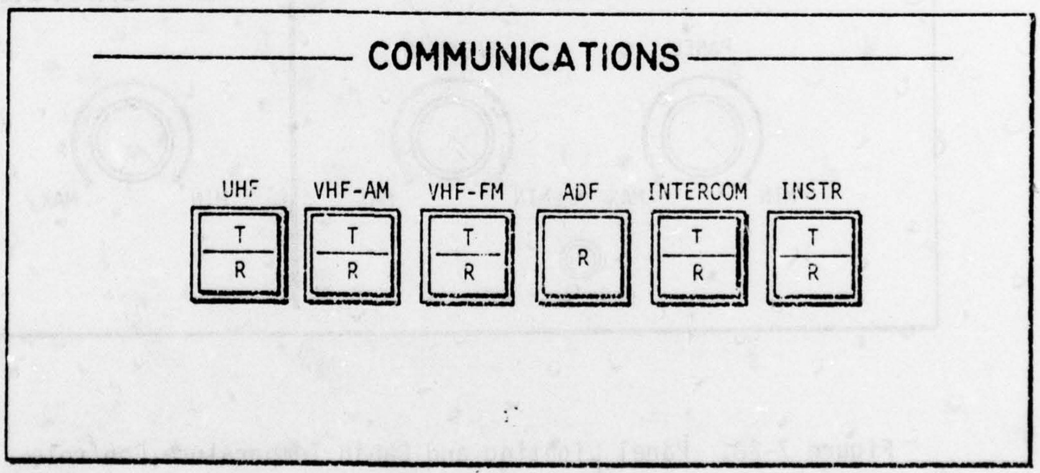



Figure 7-27. Communications Panel

Except for ADF, which has only a receive capability, there are three states for the other pushbuttons. When the R portion of the pushbutton is illuminated, the instructor hears all transmissions made by the trainee on the selected facility, regardless of frequency selection. When the T and R portions are illuminated, the instructor may receive as before and also transmit over that facility. When neither T or R is illuminated, the instructor does not receive nor can he transmit over the facility.

Manual selection of discrete recorded messages to transmit Air Traffic Control (ATC) messages, for example, is provided through a CRT control page(s) line. This approach is taken to avoid thumbwheel switches or light emitting diodes (LED) readouts on the instructor's panel. The CRT page line also describes the message contained on the voice recorder channel, whereas any other method requires reference by the instructor to some table to determine what is on any channel.

7.4.5.9 Panel Lighting and Cabin Temperature Controls. The panel lighting and cabin temperature controls allow the instructor to vary the pushbutton lighting, console overhead lighting, and cabin temperature (Figure 7-28). A lamp test switch is also provided.

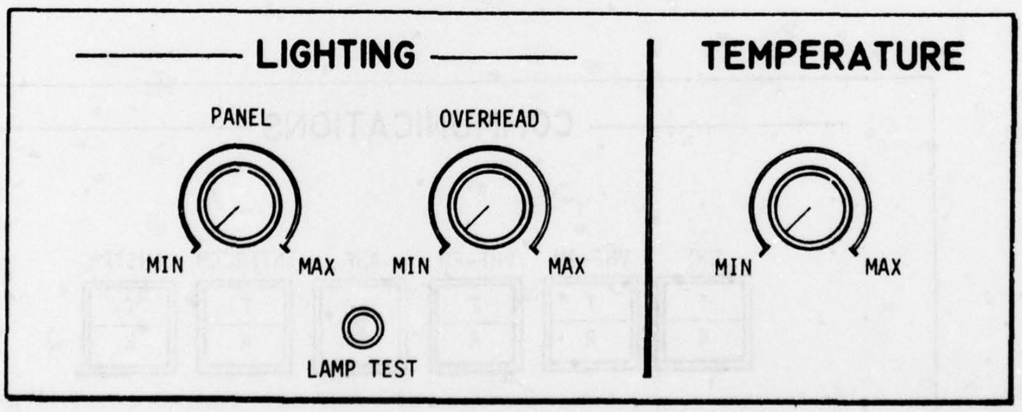



Figure 7-28. Panel Lighting and Cabin Temperature Controls

7.4.5.10 Previously Listed Controls. The description of the following controls can be found in the section listed:

| | | Paragraph |
|---|---|---|
| TIME HISTORY PLOTTER CONTROLS | (Figure 7-10) | 7.4.3.3 |
| STORE/RECALL CONTROLS | (Figure 7-12) | 7.4.4.1.4 |
| LESSON PLAN CONTROLS | (Figure 7-18) | 7.4.4.3.2 |
| RECORD/PLAYBACK CONTROLS | (Figure 7-11) | 7.4.4.1.2 |
| MAPS CONTROL | (Figure 7-8) | 7.4.3.2 |

7.4.6 Miscellaneous Instructor Modules

7.4.6.1 General. The following paragraphs describe other items of hardware to be included with the CRT display system and control panels. The items of equipment suggested are:

(a) Visual repeat monitors to enable instructors to monitor trainee visionics displays such as the Target Acquisition Designation System (TADS) and the Pilot's Night Visual System (PNVS).

(b) Voice recorders to provide voice commentary for demonstrations and enable background communications simulation.

(c) Hardcopy unit to provide records for debriefing purposes.

7.4.6.2 Visual Repeat Monitors. Repeat monitors are suggested for each instructor station to enable monitoring of the trainee's respective visionics equipment displays. A color monitor repeats the gunner's view through his TADS and PNVS, and a black-and-white monitor is used to repeat the pilot's view through his PNVS. The monitors should have a minimum 14-inch diagonal and a resolution of at least 875 lines for compatibility with the visual system. The CRT monitors incorporated into the instructor's consoles should be units similar to those used by the visual system in displaying the views through the visionics equipment.

7.4.6.3 Voice Recorders. At least two (one/cockpit), possibly three, voice recorders are recommended. The recorders would be used for the following:

. To record all communications during record/playback

. To provide maneuver demonstration voice commentary

. To provide prompting

. To interject tactical scenario messages

. To provide ATC messages

The recorders must allow quick random access (10 seconds) to short messages, with the channel selected through the instructor's facility.

For lack of information, no product recommendation can be made at this time.

Suggested instructor controls for this feature are included in paragraph 7.4.5.8.

7.4.6.4 Hardcopy Unit. Ideally, two hardcopy units, one in each cockpit, are desirable. If the hardcopy facility is outside the cockpits, only one would be required; however, the instructors would have no access to the hardcopies until the training session was over. It would also be disastrous if the hardcopy unit jammed or ran out of paper and the instructor were unaware of this. The records generated by the hardcopy feature are a very important part of the debriefing session and the trainee's permanent performance file.

Since the Sanders Graphic 7 is a strokewriting type system, there is no compatible video output that can be used for hardcopy purposes. There are two ways a hardcopy can then be generated. One is to use the Sanders hardcopier unit, which produces clear images on 8½ x 11 inch paper for a cost of $17,000. However, some extra interface is required, the price of two units being in excess of $34,000. Another method would be to use a standard printer/plotter (e.g., Versatec 1100A). Software is used to emulate Graphic 7 instructions and build a disc file which is a bit map representation of the CRT image. The subsequent disc file is then dumped on the printer/plotter. CAE has already implemented this system in conjunction with a Sanders ADDS 500.

The software approach has the following advantages:

- Hardcopy requests easily queued
- Quick release of monitor after hardcopy request
- Previously implemented

The hardware approach has the advantage that minimum software attention is necessary, and servicing, if ever required, is from the same manufacturer who supplies the display system. Queuing of hardcopies can only be accomplished by adding extra memory to the display system.

Better overall performance is obtained with the software approach and, although it is referenced in other sections, a more detailed cost effectiveness analysis is required before any firm recommendation can be made.

# SECTION 8

## COMPUTER AND PERIPHERAL ANALYSIS

## 8.1 INTRODUCTION.

The computer system for the AH-64 flight and weapons simulator will be required to perform all the computations necessary to reproduce the aircraft's flight characteristics while simultaneously controlling a realistic training environment. These computations must take place in real time; that is to say, the simulator must have the same reference to time as an actual training mission.

This section of the AH-64 FWS Study investigates the requirements imposed on a simulator computer and recommend selections of devices and software.

The first step in studying the advantages of different equipment was to estimate the AH-64 simulator requirements and propose a basic configuration to meet all simulation needs. This was done by taking into account the study requirements of a 32-bit minicomputer configuration with 100% spare time and memory.

A baseline configuration having been fixed, it was possible to explore the selective merits of available CPU's to meet AH-64 computational requirements.

The factors that will be considered are:

. Performance in a simulator environment

. Time and memory requirements

. I/O structure and data rates

. Ease of interfacing to standard and non-standard peripherals

. Availability of support software

. Cost

. Expandability

For the purposes of this study it is felt that the CPU is the primary item of investigation and that vendors can generally supply similar perepheral devices at similar cost. For this reason when discussing peripherals the recommended characteristics are itemized in the understanding that equipment to that specification can be obtained for what proves to be the best CPU.

The interfacing requirements of the special purpose AH-64 hardware are presently still under investigation. Some approaches can be recommended but a more detailed study cannot be carried out without more detailed AH-64 hardware knowledge.

The relative merits of high level and assembler level languages as a basis for simulation are studied in paragraph 8.4. With the advent of Fortran IV enhancements it may now be possible to provide an optimum mixture of both language types.

Development of an operating system for the new 32-bit computer is also discussed in depth in paragraph 8.4 with CAE's background in the creation of a TI980 operating system providing a firm basis for the recommendation of useful simulator features.

## 8.2 COMPUTER COMPLEX CONFIGURATION USED FOR ANALYSIS

8.2.1 Considerations in Configuration Choice. The choice of computer complex configuration for analysis was based on a number of considerations.

- The configuration must be capable of allowing 100% spare memory and time when applied to the AH-64.
- The system must be expandable to allow for future adaption to systems with larger requirements.
- Computers must be general purpose minicomputers.

For these reasons a twin CPU configuration was chosen. The configuration demonstrates the capabilities of CPU's understudy to operate in multi CPU configuration and the memory and time requirements based on estimates outlined in paragraph 8.3.1.3 suggest it must.

The computer configuration chosen to represent a preliminary configuration for the AH-64 simulator and to be used as the basis of study is shown in Figure 8-1 . It is a dual CPU system complemented by interfaces to system consoles, mass storage devices, trainer modules, instructor's stations, visual system modules and program development/maintenance facility.

8.2.1.1 CPU. The CPU and computer module characteristics chosen for study are as follows:

(a) The computer module consisting of two CPU's configured in a master-slave relationship. Both computers should have dedicated memory and access to a shared memory area.

(b) An inter CPU link to provide for the synchronization of the two computers. The inter CPU link is not required to transfer large amounts of data from one CPU to the other. It is sufficient for it to interrupt the remote CPU in order to inform it of a request to transmit or receive, while a portion of the shared memory is used to buffer the data.

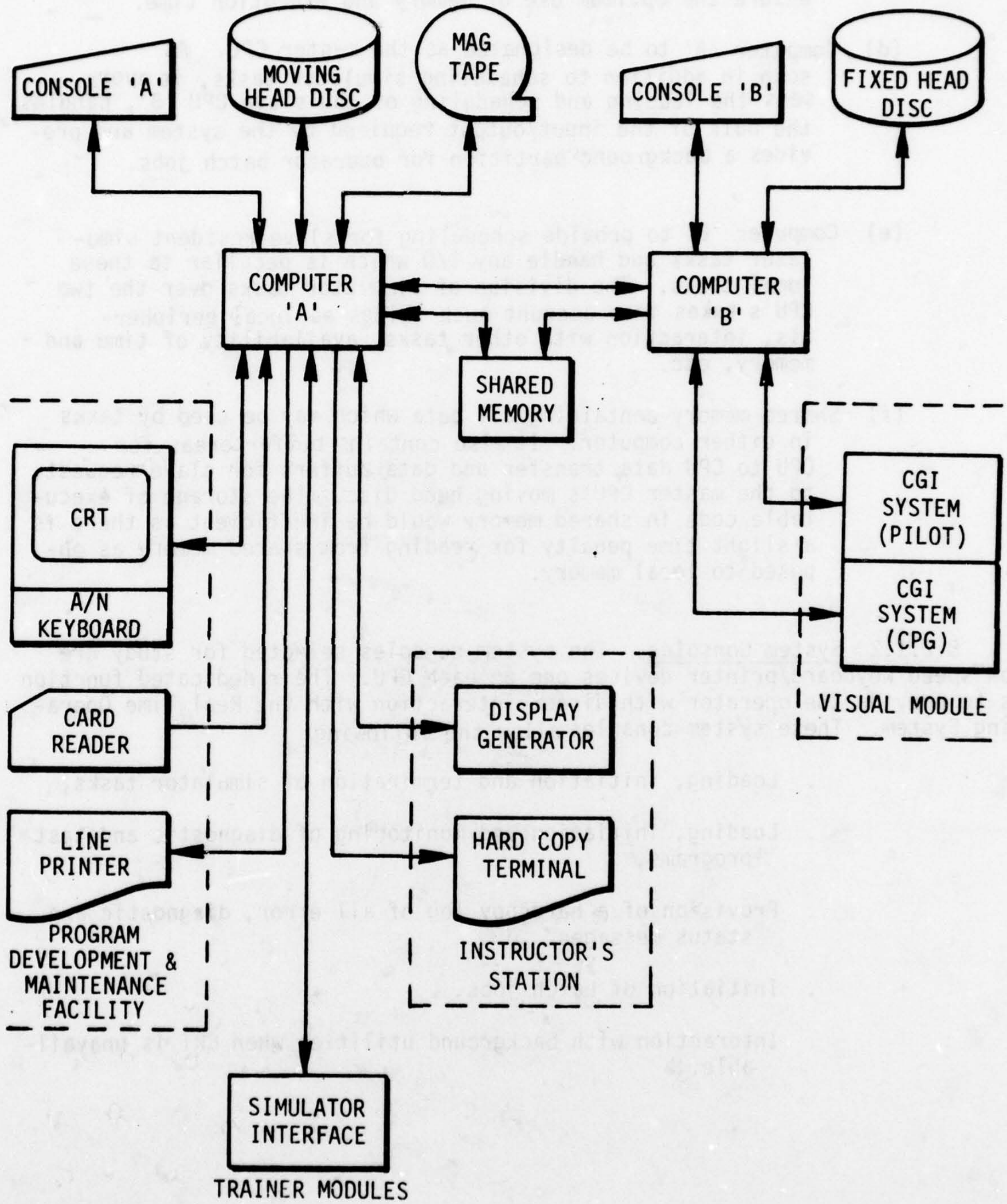



Figure 8-1. Block Diagram of Computer Complex

(c) The software distribution over the two CPU's such as to ensure the optimum use of memory and execution time.

(d) Computer 'A' to be designated as the master CPU. As such in addition to scheduling simulator tasks, it oversees the loading and scheduling of the slave CPU 'B', handles the bulk of the input/output required by the system and provides a background partition for operator batch jobs.

(e) Computer 'B' to provide scheduling for slave resident simulator tasks and handle any I/O which is peculiar to these local tasks. The division of simulator tasks over the two CPU's takes into account such things as local peripherals, interaction with other tasks, availability of time and memory, etc.

(f) Shared memory containing all data which may be used by tasks in either computer. It also contains buffer areas for CPU to CPU data transfer and data buffers for slave requests to the master CPU's moving head disc. The storage of executable code in shared memory would be inefficient as there is a slight time penalty for reading from shared memory as opposed to local memory.

8.2.1.2 System Consoles. The system consoles selected for study are low speed keyboard/printer devices one on each CPU. Their dedicated function is to provide the operator with direct interaction with the Real Time Operating System. These system consoles allow the following:

. Loading, initiation and termination of simulator tasks,

. Loading, initiation and monitoring of diagnostic and test programs,

. Provision of a hardcopy log of all error, diagnostic and status messages,

. Initiation of batch jobs,

. Interaction with background utilities when CRT is unavailable.

8.2.1.3 Mass Storage Devices. The proposed mass storage devices include a moving head disc (MHD), magnetic tape (MT) and fixed head disc (FHD).

(a) Moving Head Disc. The MHD contains all current files and temporary storage areas.

The current files include the following:

- Load modules for operating system, simulator tasks, utilities and diagnostics,
- Source and object files for simulator programs,
- Data files for CRT pages, lesson plan, visual data base, etc. as dictated by the simulator requirements.

Files which are not likely to be accessed during simulation or program integration are kept on the backup media.

Temporary storage area provides for: Record and playback, input and output spooling, program roll in/roll out, etc.

(b) Magnetic Tape. A single MT drive is available to the system for the purposes of providing an archival storage media for program and data files.

The storage and retrieval of data can be done on-line. For example, if a previous revision of a program is needed, the tape containing the file is mounted and a tape to disc copy utility invoked. Backup of the disc's load modules and a library of lesson plans or visual data bases can also be kept on mag tape.

(c) Fixed Head Disc. The FHD contains the working data base for visual safety and line of sight calculations as dictated by the visual system requirements.

8.2.1.4 Trainer Module Interface. The trainer module (simulator) interface selected consists of standard building blocks and modules which provide analog and digital inputs and outputs, synchro inputs and outputs and special module providing serial digital channels to visionics and target designation system. The interface runs synchronously permitting the computer to monitor and control the flight compartments, control forces and motion systems of the simulator.

8.2.1.5 Instructor's Station. The instructor's station in the module configuration interfaces to computer 'A' via a graphic display generator and the trainer module interface.

The graphic display generator drives all the displays associated with the instructor's station. These displays are strictly output devices which provide both graphic and character readout. A hardcopy device is associated with the instructor's station in order to provide hardcopies of the graphic display images.

All discrete input and output, such as pushbuttons and indicator lamps, interface to the computer through the trainer module interface. The same is true for any analog input/output that may be required.

8.2.1.6 Visual System. The recommended visual approach is to use either a full CGI system or a hybrid system including CGI and model board/CCTV.

The recommended CGI system is based on the DEC PDP-11 family of computers. The simulator computers would therefore need to interface to the PDP-11 Unibus.

The model board/CCTV portion of a hybrid visual system would interface to the simulation computer via the trainer module interface. The X, Y and Z coordinates can each be represented by 16 discrete outputs in order to position the camera.

8.2.1.7 Program Development/Maintenance Facility. It is recommended that a set of programmer/operator peripherals be included in the configuration to facilitate the development and maintenance of simulator programs. These peripherals consist of an alphanumeric CRT/keyboard, a punched card reader and a medium speed line printer.

8.2.1.7.1 Alphanumeric CRT/Keyboard. The CRT/keyboard provides the programmer with an interaction terminal with the capability of editing data bases and programs, assembling and compiling programs, debugging new programs, obtaining memory or mass storage dumps, doing media conversion, etc.

The invocation of all background utilities is possible from this terminal.

8.2.1.7.2 Punched Card Reader. ASCII files, either data or source programs, can be prepared offsite at a keypunch centre, then entered into the system via the card reader. This reduces the time during which the CRT/keyboard is tied up.

Job control strings can also be read by the card reader during batch processing.

8.2.1.7.3 Line Printer. The line printer produces all hardcopies requested by the system other than error messages and graphic hardcopy.

Hardcopies produced by the line printer include the following:

- Assembly listings
- Memory and mass storage dumps
- Source listings
- Data base listings

All data destined for the line printer is spooled, that is to say, it will be buffered until the line printer is free. This allows one listing to finish before a line on another listing is printed. It also avoids a lockout of the printer as a resource during the printing of one list.

## 8.3 32-BIT COMPUTER HARDWARE ANALYSIS

8.3.1 Computer. CAE has been closely monitoring the development of 32-bit computers by both System Engineering Laboratories (SEL) and Interdata since their introduction two years ago. CAE believes the 32-bit computer is the logical successor to the TI-980 which is presently being delivered with our simulators. CAE is currently proposing SEL and Interdata 32-bit machines in its Data Acquisition and Control Systems, Simulators and Air Traffic Control Systems.

Other 32-bit computers are available, such as the low end of the IBM 370 series and the DEC system 10. They are discounted as they do not fit the description of a minicomputer and on the basis of price.

However, other 32-bit minicomputers are in the planning and development stage. These minicomputers may be superior to those already evaluated and may be available in time to be utilized for the AH-64 simulator. Owing to the strong competition between manufacturers the characteristics of minicomputers are unavailable until the formal announcement is made. Only when ready to go into full scale production does a manufacturer publish the technical capability of its minicomputer. CAE intends to extend the evaluation and comparison of 32-bit minicomputers to include new models as data becomes available.

CAE believes that it is in the best interest of the program to delay the selection of a specific computer as long as possible.

8.3.1.1 <u>CPU Characteristics</u>. A comparison of the characteristics of the currently available SEL and Interdata 32-bit computers is found in Table 8-1. The comparison was made from data obtained from manufacturers' publications and covers five models:

- Interdata 7/32
- Interdata 8/32
- SEL 32/35
- SEL 32/55
- SEL 32/75

The following points are of interest when comparing the computers itemized in Table 8-1:

- The Interdata computers have a 16-bit wide I/O bus. This was probably done by Interdata in order to maintain compatability with existing device interfaces and controllers. Although the 7/32 is nominally a 32-bit machine, it would appear from the instruction execution times specified in Paragraph 8.3.1.2 that the memory bus is also only 16 bits wide.
- Interdata provides multiple register sets. As the register set used is defined by the Program Status Word (PSW), the overhead incurred by saving and restoring registers during context switching can be avoided.

TABLE 8-1. COMPUTER CHARACTERISTIC COMPARISON (SHT. 1 OF 3)

| | Interdata 7/32 | Interdata 8/32 | SEL 32/35 | SEL 32/55 | SEL 32/75 |
|---|---|---|---|---|---|
| **Bus Width (bits):** | | | | | |
| Memory | (16) | 32 | 32 | 32 | 32 |
| I/O | 16 | 16 | 32 | 32 | 32 |
| **Registers:** | | | | | |
| Register length (bits) | 32 | 32 | 32 | 32 | 32 |
| Number of general purpose registers | 16 (2 sets) | 16 (2-8 sets) | 8 | 8 | 8 |
| | 15 registers in each set can be used for indexing | | 3 of the general purpose registers can be used for indexing | | |
| **Instruction Set:** | | | | | |
| Number of instructions | 227 | 173 | 152 | | 163 |
| Instruction Length (bits) | 16,32,48 | | 16,32 | | 16,32 |
| Floating point | Single precision firmware and Optional High Speed Hardware | Optional High Speed Hardware | Standard Firmware or Optional High Speed Hardware | | |

TABLE 8-1. COMPUTER CHARACTERISTIC COMPARISON (SHT. 2 OF 3)

| | Interdata 7/32 | Interdata 8/32 | SEL 32/35 | SEL 32/55 | SEL 32/75 |
|---|---|---|---|---|---|
| Addressing modes: | | | | | |
| Direct | Yes | | | Yes | |
| Indirect | No | | | Yes (multilevel) | |
| Immediate | Yes | | | Yes | |
| Indexed | Yes | | | Yes | |
| Prog. Counter Relative | Yes | | | No | |
| Writable Control Store | No | Yes, 512x32 bits | No | No | Yes, 2048x 64 bits |
| Execution times | | See Tables | 8-4&8-5 | | |
| Number of priority interrupts | 1024(max) | 1024(max) 4 immediate priority levels | 128(max) 10 basic interrupts are dedicated to internal functions | | 112(max) |
| | 8 internal interrupts | | | | |
| Memory cycle time | 750 nsec or 1000 nsec | | 900 nsec | 600 nsec | 900&/or 600nsec |
| Memory type | | Core | Core | Core | Core |
| Memory expansion | | 1024 Kb | 524K b | 1024Kb | 8Mb-600nsec 16Mb-900nsec |
| Memory parity | 1 bit/16 bit word (Optional) | | 1 bit/8 bit byte | | |

TABLE 8-1. COMPUTER CHARACTERISTIC COMPARISON (SHT. 3 OF 3)

| | Interdata 7/32 | Interdata 8/32 | SEL 32/35 | SEL 32/55 | SEL 32/75 |
|---|---|---|---|---|---|
| Memory Overlapping | - | - | Yes | Yes | Yes |
| Memory Interleaving | No | Yes | - | - | - |
| Memory Protect | Yes | | Yes | | |
| Protected Page Size | 256 bytes | | 1024 bytes | | |
| Look ahead feature | | Yes, 2-64 bit look ahead stacks | Yes, instructions are fetched concurrently with execution and decoding of previous instructions. | | |
| Common Memory | Yes | | Yes | | |
| Input/Output Bus | Multiplexer Bus for slow to medium speed devices. 'Auto Driver Channel' provides automatic interrupt handling. Direct Memory Access for high speed devices. 7 DMA ports are available. | | SEL Bus, a bidirectional bus with a transfer rate of 26.67 M bytes/sec. Devices are interfaced through intelligent micro programmable I/O cards (IOM's) some of which can drive more than one device. | | |

- The instruction sets offered by both manufacturers provide the same basic functions. The short format instructions can be used more effectively on an Interdata machine since it does not impose the full word alignment restriction as is done on SEL. SEL on the other hand provides a fast firmware floating point as a standard feature, whereas Interdata does not have any firmware floating point on the 8/32 and only single precision

- Indirect addressing is a powerful programming tool in an application such as a simulator where data and pointers are kept in a common area. Indirect addressing is provided only by SEL.

- Writable Control Store (WCS) can complement the standard instruction set with a library of selected macro instructions. WCS is optional on the Interdata 8/32 and SEL 32/75. The advantages of WCS in simulation would be offset by its cost and the cost of developing and maintaining microcoded software which is reputed to be 10 times more difficult to work with than the assembler.

- Both manufacturer's machines provide an adequate number of interrupts. The standard internal interrupts include: power fail/restart, illegal instruction, memory parity, protect violation, etc.

- Currently only core memory is supplied by SEL and Interdata on their 32-bit computers. Only the SEL 32/35, which has a maximum memory capacity of 512K bytes, may not meet the 100% spare memory requirements. Memory parity is optional with all Interdata machines.

- Memory overlapping and interleaving coupled with a look ahead feature will increase the computer's effective throughput by avoiding the lockout of all memory by a single memory request.

- Memory protect is essential in a real time multi tasking environment. SEL may cause more memory wastage than Interdata due to its larger protect page size.

- Interdata offers both a multiplexer bus for slow to medium speed devices and a direct memory access (DMA) channel for high speed devices. The multiplexer bus will interrupt the CPU after each 16-bit transfer. The DMA has direct access to memory but can only transfer 16-bit per memory request.

. SEL's I/O is based on a high speed 32-bit wide data path between the CPU, memory and the device interfaces. The I/O interfaces are microprogrammable to control the data transfer. The separation of I/O related processing and program execution allows for more efficient CPU usage. The CPU needs only to initiate the I/O transfer and to acknowledge its completion, then the I/O microprocessor in each interface handles all protocol with device, data formatting, error checking, etc. The cost of the I/O microprocessor interface is generally higher than that of nonintelligent device interfaces but the difference in cost can be justified by the enhanced overall throughput provided.

8.3.1.2 CPU Performance Evaluation. In evaluating 32-bit computers for the AH-64 simulator, execution time and memory requirements were the prime factors considered. In order to arrive at realistic comparative figures, all computers were measured against the TI980. CAE has built a dozen simulators using this computer and has a particularly good knowledge of the simulation requirements using the TI980.

Samples of about 10,000 instructions of an F-28 simulator were analyzed to derive a representative instruction mixture. Two basic types of programs were considered. Those involving extensive arithmetic as characterterized by the flight programs. These were labelled type A (arithmetic). Those containing both arithmetic and logic operation mix are typical of the ancillaries programs. These were labelled type L (Logic).

In the case of the SEL computers, the throughput of the CPU is a function of the memory speed. The Interdata 7/32 and 8/32 perform differently due to the difference in machine architecture. For the purposes of memory and time comparison, the following computer/memory configurations were considered:

. SEL 32 with 900 nanosecond memory

. SEL 32 with 600 nanosecond memory

. Interdata 7/32 with 750 nanosecond core

. Interdata 8/32 with 750 nanosecond core

The rules in compiling the comparison tables were as follows:

(a) In TI assembler, conditional skips and unconditional branches are grouped together and the assumption was made that half of the skips would fail. Therefore the number of branches for both of the 32-bit machines was reduced by half of the number of skips found in the TI.

(b) Both of the 32-bit machines have a better instruction repertoire for Boolean operations on memory than the TI980. This means that fewer load instructions are needed. The number of load/store instructions were reduced by 30% of the register to register Boolean, and 30% of the register Boolean instruction were counted as memory Boolean.

(c) Except in the case of floating point arithmetic, single precision refers to operations on a 16-bit halfword; similarly, double precision refers to operations on 32-bit words. For 32-bit machines, load/store and all fixed point arithmetic were considered to be double precision.

(d) Floating point arithmetic was considered to be single precision. By definition it operates on a 32-bit operand which provides a 24 significant bit resolution. It is reasonable to expect that certain functions, however, would need double precision even in floating point.

(e) 20% of arithmetic instructions on the TI980 are followed by a shift instruction for scaling in fixed point arithmetic. This was subtracted from the number of shift instructions on the 32-bit machines considering the use of floating point eliminates scaling.

(f) On the Interdata machines, the bit manipulation instructions require the bit offset be loaded into a register prior to execution and no instructions allow the manipulation of register bits. Therefore, the number of load/store instructions was increased by the number of memory bit manipulation instructions and the register bit manipulation instructions were counted as memory bit instructions.

(g) Interdata provides register to register floating point, this was considered where possible.

(h) Typically, 20% of the TI980 memory reference instructions require an indirect access, as against self relative, base relative, immediate or absolute addressing modes. Therefore 150 nanoseconds (20% of one memory access) was added to the TI980 memory reference instruction times. There is no similar penalty on a 32-bit machine since all memory reference instruction contains the address as part of a 32-bit instruction. The average TI980 memory reference instruction length was considered to be 1.2 16-bit words (2.4 bytes).

(i) SEL disallows full word instructions to start on anything but a fullword boundary. If necessary a no operation (NO OP) instruction will be inserted following a halfword instruction. The average length of a halfword instruction, therefore, was taken to be 3 bytes.

(j) 20% of the compare instructions are register compares, the remaining 80% compare register and memory. Both the average memory and timing requirements have been adjusted for this.

(k) For Interdata it was assumed that 25% of the branch instructions were short format by either branching program counter relative or branching to an address contained in a register.

(l) All shift time estimates were based on a 4-bit logical shift on a 16-bit halfword.

(m) Execution times for the TI980, and Interdata's 7/32 and 8/32 are as published by the manufacturer. SEL's execution times for 900 nanoseconds memory were supplied unofficially by the manufacturer and appended with a note saying that 'Most of the instruction times given are one case instruction times. They should not be considered best cases, worst cases or typical'. SEL 600 nanoseconds memory execution times were derived from the above by subtracting 300, 600 or 900 nanoseconds for instruction which require one, two or three memory accesses respectively.

Using the above rules, instruction equivalents for a 1000 word TI program were arrived at as shown in the appropriate columns in Tables 8-2 and 8- 3. Note that the instruction counts for both 32-bit machines are less than that of the TI980.

The comparison of execution time was done by taking the baseline memory and execution time for the various instruction types for both floating point and fixed point arithmetic (Tables 8-4 and 8-5) and multiplying by the instruction requirements of Tables 8-2 and 8-3.

The results listed in Tables 8-6 through 8-9 show the relative memory and timing merits of each computer for arithmetic and logical program types using fixed and floating point. Table 8-10 contains a summary of Tables 8-6 to 8-9. It is evident from Table 8-10 that the Interdata 7/32 is unsuitable for simulation purposes as the execution time is twice that of the TI980. Assuming the use of high speed floating point hardware, the Interdata 8/32 is faster than the SEL (600 nanoseconds) by 8% (high speed floating point) in A-type programs but slower by 15% for L-type programs. The 8/32's faster time is accounted for by a faster arithmetic instruction set (fixed and floating point). This advantage is lost, however, when doing conditional branches and bit manipulation instructions. Interdata will require 4-9% less memory than SEL.

TABLE 8-2. CPU INSTRUCTION MEMORY REQUIREMENTS - FLOATING POINT ARITHMETIC

| | TI 980 | | SEL | | INTERDATA | |
|---|---|---|---|---|---|---|
| | A-TYPE | L-TYPE | A-TYPE | L-TYPE | A-TYPE | L-TYPE |
| Single precision load/store | 257 | 383 | 0 | 0 | 0 | 0 |
| Double precision load/store | 65 | 2 | 321 | 378 | 326 | 396 |
| Single precision add/sub. | 66 | 61 | 146 | 68 | 98 | 64 |
| Register add/sub. | 48 | 4 | 0 | 0 | 48 | 4 |
| Double precision add/sub. | 32 | 3 | 0 | 0 | 0 | 0 |
| Single precision multiply | 99 | 37 | 114 | 38 | 114 | 38 |
| Double precision multiply | 15 | 1 | 0 | 0 | 0 | 0 |
| Single precision divide | 5 | 5 | 6 | 5 | 6 | 5 |
| Double precision divide | 1 | 0 | 0 | 0 | 0 | 0 |
| Branch | 85 | 100 | 55 | 35 | 55 | 35 |
| Register shift | 98 | 33 | 45 | 11 | 45 | 11 |
| Compare | 10 | 36 | 10 | 36 | 10 | 36 |
| Conditional skip/branch | 61 | 131 | 61 | 131 | 61 | 131 |
| Register to register | 141 | 85 | 141 | 85 | 141 | 85 |
| Add/sub to memory | 0 | 5 | 0 | 5 | 0 | 5 |
| Register Boolean | 4 | 22 | 3 | 15 | 3 | 15 |
| Memory Boolean | 8 | 60 | 9 | 67 | 9 | 67 |
| Test memory bit | 4 | 14 | 4 | 14 | 4 | 19 |
| Set/clear memory bit | 1 | 4 | 1 | 4 | 1 | 13 |
| Test register bit | 0 | 5 | 0 | 5 | 0 | 0 |
| Set/clear register bit | 0 | 9 | 0 | 9 | 0 | 0 |
| Number of Instructions | 1000 | 1000 | 917 | 906 | 922 | 918 |

TABLE 8-3. CPU INSTRUCTION MEMORY REQUIREMENTS - FIXED POINT ARITHMETIC

| | TI 980 | | SEL | | INTERDATA | |
|---|---|---|---|---|---|---|
| | A-TYPE | L-TYPE | A-TYPE | L-TYPE | A-TYPE | L-TYPE |
| Single precision load/store | 257 | 383 | 0 | 0 | 0 | 0 |
| Double precision load/store | 65 | 2 | 321 | 378 | 326 | 396 |
| Single precision add/sub. | 66 | 61 | 0 | 0 | 0 | 0 |
| Register add/sub. | 48 | 4 | 48 | 4 | 48 | 4 |
| Double precision add/sub. | 32 | 3 | 98 | 64 | 98 | 64 |
| Single precision multiply | 99 | 37 | 0 | 0 | 0 | 0 |
| Double precision multiply | 15 | 1 | 114 | 38 | 114 | 38 |
| Single precision divide | 5 | 5 | 0 | 0 | 0 | 0 |
| Double precision divide | 1 | 0 | 6 | 5 | 6 | 5 |
| Branch | 85 | 100 | 55 | 35 | 55 | 35 |
| Register shift | 98 | 33 | 98 | 33 | 98 | 33 |
| Compare | 10 | 36 | 10 | 36 | 10 | 36 |
| Conditional skip/branch | 61 | 131 | 61 | 131 | 61 | 131 |
| Register to register | 141 | 85 | 141 | 85 | 141 | 85 |
| Add/sub. to memory | 0 | 5 | 0 | 5 | 0 | 5 |
| Register Boolean | 4 | 22 | 3 | 15 | 3 | 15 |
| Memory Boolean | 8 | 60 | 9 | 67 | 9 | 67 |
| Test memory bit | 4 | 14 | 4 | 14 | 4 | 19 |
| Set/clear memory bit | 1 | 4 | 1 | 4 | 1 | 13 |
| Test register bit | 0 | 5 | 0 | 5 | 0 | 0 |
| Set/clear register bit | 0 | 9 | 0 | 9 | 0 | 0 |
| Number of Instructions | 1000 | 1000 | 970 | 928 | 975 | 940 |

TABLE 8-4. BASELINE INSTRUCTION MEMORY AND EXECUTION TIMES - FLOATING POINT ARITHMETIC

| | Memory-Requirement (bytes) | | | Execution Times (Microseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | TI 980 | SEL | Interdata | TI 980 | SEL (900 nsec) | SEL (600 nsec) | Interdata 7/32 | Interdata 8/32 |
| Single precision load/store | 2.4 | 4.0 | 4.0 | 1.9 | 1.8 | 1.2 | 2.75 | 1.25 |
| Double precision load/store | 2.4 | 4.0 | 4.0 | 2.9 | 1.8 | 1.2 | 3.25 | 1.25 |
| Single precision add/sub. | 2.4 | 4.0 | 4.0 | 1.9 | 3.3/2.55 | 2.7/1.95 | 12.0/6.0 | */1.85 |
| Register add/sub. | 2.0 | 3.0 | 2.0 | 1.25 | 0.9 | 0.6 | 11.0/3.75 | */1.0 |
| Double precision add/sub. | 2.4 | 4.0 | 4.0 | 2.9 | 6.3/3.5 | 5.4/2.6 | */9.75 | */3.38 |
| Single precision multiply | 2.4 | 4.0 | 4.0 | 6.4 | 7.3/4.55 | 6.7/3.95 | 29.25/12.75 | */2.5 |
| Double precision multiply | 4.0 | 4.0 | 4.0 | 42.7 | 24.9/6.5 | 24.0/5.6 | */21.25 | */4.9 |
| Single precision divide | 2.4 | 4.0 | 4.0 | 7.9 | 9.3/4.8 | 8.7/4.2 | 48.5/13.25 | */4.45 |
| Double precision divide | 4.0 | 4.0 | 4.0 | 31.0 | 43.1/8.0 | 42.2/7.1 | */22.0 | */9.2 |
| Branch | 2.4 | 4.0 | 3.5 | 1.4 | 1.8 | 1.2 | 1.95 | 1.89 |
| Register shift | 2.0 | 3.0 | 2.0 | 1.75 | 1.8 | 1.5 | 2.75 | 0.91 |
| Compare | 2.3 | 3.8 | 3.4 | 1.8 | 1.6 | 1.1 | 3.0 | 1.6 |
| Conditional skip/branch | 2.4 | 4.0 | 3.5 | 1.0 | 1.8 | 1.2 | 2.0 | 1.95 |
| Register to register | 2.0 | 3.0 | 2.0 | 1.25 | 0.9 | 0.6 | 1.0 | 0.41 |
| Add/sub. to memory | 2.4 | 4.0 | 4.0 | 2.9 | 2.7 | 1.8 | 5.0 | 2.0 |
| Register Boolean | 2.0 | 3.0 | 2.0 | 1.25 | 0.9 | 0.6 | 1.0 | 0.41 |
| Memory Boolean | 2.4 | 4.0 | 4.0 | 1.9 | 1.8 | 1.2 | 3.25 | 1.25 |
| Test memory bit | 4.0 | 4.0 | 4.0 | 2.75 | 1.8 | 1.2 | 5.75 | 3.68 |
| Set/clear memory bit | 4.0 | 4.0 | 4.0 | 3.25 | 2.4 | 1.8 | 6.0 | 4.51 |
| Test register bit | 2.0 | 3.0 | - | 1.25 | 0.9 | 0.6 | - | - |
| Set/clear register bit | 2.0 | 3.0 | - | 1.0 | 0.9 | 0.6 | - | - |

NOTE: Floating point execution times are given in firmware and High Speed Floating Point (HSFP) hardware.

* indicates the operation is not available.

TABLE 8-5. BASELINE INSTRUCTION MEMORY AND EXECUTION TIMES - FIXED POINT ARITHMETIC

| | Memory Requirement (bytes) | | | Execution Times (Microseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | TI 980 | SEL | Interdata | TI 980 | SEL | | Interdata | |
| | | | | | (900 nsec) | (600 nsec) | 7/32 | 8/32 |
| Single precision load/store | 2.4 | 4.0 | 4.0 | 1.9 | 1.8 | 1.2 | 2.75 | 1.25 |
| Double precision load/store | 2.4 | 4.0 | 4.0 | 2.9 | 1.8 | 1.2 | 3.25 | 1.25 |
| Single precision add/sub. | 2.4 | 4.0 | 4.0 | 1.9 | 1.8 | 1.2 | 2.75 | 1.25 |
| Register add/sub. | 2.0 | 3.0 | 2.0 | 1.25 | 0.9 | 0.6 | 1.0 | 0.41 |
| Double precision add/sub. | 2.4 | 4.0 | 4.0 | 2.9 | 1.8 | 1.2 | 3.25 | 1.25 |
| Single precision multiply | 2.4 | 4.0 | 4.0 | 6.4 | 6.3 | 5.7 | 6.0 | 4.69 |
| Double precision multiply | 4.0 | 4.0 | 4.0 | 42.7 | 6.2 | 5.6 | 24.0 | 3.58 |
| Single precision divide | 2.4 | 4.0 | 4.0 | 7.9 | 9.6 | 9.0 | 13.0 | 8.61 |
| Double precision divide | 4.0 | 4.0 | 4.0 | 31.0 | 9.5 | 8.9 | 82.75 | 6.0 |
| Branch | 2.4 | 4.0 | 3.5 | 1.4 | 1.8 | 1.2 | 1.25 | 1.89 |
| Register shift | 2.0 | 3.0 | 2.0 | 1.75 | 1.8 | 1.5 | 2.75 | 0.91 |
| Compare | 2.3 | 3.8 | 3.4 | 1.8 | 1.6 | 1.1 | 3.0 | 1.6 |
| Conditional skip/branch | 2.4 | 4.0 | 3.5 | 1.0 | 1.8 | 1.2 | 2.0 | 1.95 |
| Register to register | 2.0 | 3.0 | 2.0 | 1.25 | 0.9 | 0.6 | 1.0 | 0.41 |
| Add/sub. to memory | 2.4 | 4.0 | 4.0 | 2.9 | 2.7 | 1.8 | 5.0 | 2.0 |
| Register Boolean | 2.0 | 3.0 | 2.0 | 1.25 | 0.9 | 0.6 | 1.0 | 0.41 |
| Memory Boolean | 2.4 | 4.0 | 4.0 | 1.9 | 1.8 | 1.2 | 3.25 | 1.25 |
| Test memory bit | 4.0 | 4.0 | 4.0 | 2.75 | 1.8 | 1.2 | 5.75 | 3.68 |
| Set/clear memory bit | 4.0 | 4.0 | 4.0 | 3.25 | 2.4 | 1.8 | 6.0 | 4.51 |
| Test register bit | 2.0 | 3.0 | - | 1.25 | 0.9 | 0.6 | - | - |
| Set/clear register bit | 2.0 | 3.0 | - | 1.0 | 0.9 | 0.6 | - | - |

TABLE 8-6. CPU MEMORY/TIME COMPARISON FOR TYPE A PROGRAMS - FLOATING POINT

| | Memory-Requirement (bytes) | | | Exectuion Times (Microseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SEL | | Interdata | |
| | TI 980 | SEL | Interdata | TI 980 | (900 nsec) | (600 nsec) | 7/32 | 8/32 |
| Single precision load/store | 616.8 | 0 | 0 | 488.3 | 0 | 0 | 0 | 0 |
| Double precision load/store | 156 | 1288 | 1308 | 188.5 | 577.6 | 385.4 | 1059.95 | 407.5 |
| Single precision add/sub. | 158.4 | 584 | 392 | 125.4 | 481.8/372.3 | 394.2/284.7 | 1176/588 | */181.3 |
| Register add/sub. | 96 | 0 | 96 | 60 | 0 | 0 | 528/180 | */48 |
| Double precision add/sub. | 76.8 | 0 | 0 | 92.8 | 0 | 0 | 0 | 0 |
| Single precision multiply | 237.6 | 456 | 456 | 633.6 | 832.2/518.7 | 763.8/450.3 | 3334.5/1453.5 | */285 |
| Double precision multiply | 60 | 0 | 0 | 640.5 | 0 | 0 | 0 | 0 |
| Single precision divide | 12 | 24 | 24 | 39.5 | 55.8/28.8 | 52.2/25.2 | 291/79.5 | */26.7 |
| Double precision divide | 4 | 0 | 0 | 31 | 0 | 0 | 0 | 0 |
| Branch | 204 | 220 | 192.5 | 119 | 99 | 66 | 107.25 | 103.95 |
| Register shift | 196 | 135 | 90 | 171.5 | 81 | 54 | 123.75 | 40.95 |
| Compare | 23 | 38 | 34 | 18 | 16 | 11 | 30 | 16 |
| Conditional skip/branch | 146.4 | 244 | 213.5 | 61 | 109.8 | 73.2 | 122 | 118.95 |
| Register to register | 282 | 423 | 282 | 176.25 | 126.9 | 84.6 | 141 | 57.81 |
| Add/sub. to memory | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Register Boolean | 8 | 9 | 6 | 5 | 2.7 | 1.8 | 3 | 1.23 |
| Memory Boolean | 19.2 | 36 | 36 | 15.2 | 16.2 | 10.8 | 29.25 | 11.25 |
| Test memory bit | 16 | 16 | 16 | 11 | 7.2 | 4.8 | 23 | 14.72 |
| Set/clear memory bit | 4 | 4 | 4 | 3.25 | 2.4 | 1.8 | 6 | 4.51 |
| Test register bit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Set/clear register bit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total memory/time | 2316.2 | 3477 | 3150 | 2879.8 | 2408.6/ 1958.6 | 1903.6/ 1453.6 | 6974.7/ 3946.2 | */ 1317.87 |
| Relative memory/time | 1.00 | 1.5 | 1.36 | 1.0 | 0.84/0.68 | 0.66/0.5 | 2.42/1.37 | */0.46 |

NOTE: Floating point execution times are given in firmware and High Speed Floating Point (HSFP) hardware.

* indicates the operation is not available.

TABLE 8-7. CPU MEMORY/TIME COMPARISON FOR TYPE A PROGRAM - FIXED POINT ARITHMETIC

| | Memory Requirements (bytes) | | | Execution Time (Microseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SEL | | Interdata | |
| | TI 980 | SEL | Interdata | TI 980 | (900 nsec) | (600 nsec) | 7/32 | 8/32 |
| Single precision load/store | 616.8 | 0 | 0 | 488.3 | 0 | 0 | 0 | 0 |
| Double precision load/store | 156 | 1288 | 1308 | 188.5 | 577.6 | 385.4 | 1059.95 | 407.5 |
| Single precision add/sub. | 158.4 | 0 | 0 | 125.4 | 0 | 0 | 0 | 0 |
| Register add/sub. | 96 | 144 | 96 | 60 | 43.2 | 28.8 | 48.0 | 19.68 |
| Double precision add/sub. | 76.8 | 392 | 392 | 92.8 | 176.4 | 117.6 | 318.5 | 122.5 |
| Single precision multiply | 237.6 | 0 | 0 | 633.6 | 0 | 0 | 0 | 0 |
| Double precision multiply | 60 | 456 | 456 | 640.5 | 706.8 | 638.4 | 2736 | 408.12 |
| Single precision divide | 12 | 0 | 0 | 39.5 | 0 | 0 | 0 | 0 |
| Double precision divide | 4 | 24 | 24 | 31.0 | 57 | 53.4 | 496.5 | 36 |
| Branch | 204 | 220 | 192.5 | 119 | 99 | 66 | 107.25 | 103.95 |
| Register shift | 196 | 294 | 196 | 171.5 | 176.4 | 147 | 269.5 | 89.18 |
| Compare | 23 | 38 | 34 | 18 | 16 | 11 | 30 | 16 |
| Conditional skip/branch | 146.4 | 244 | 213.5 | 61 | 109.8 | 73.2 | 122 | 118.95 |
| Register to register | 282 | 423 | 282 | 176.25 | 126.9 | 84.6 | 141 | 57.81 |
| Add/sub. to memory | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Register Boolean | 8 | 9 | 6 | 5 | 2.7 | 1.8 | 3 | 1.23 |
| Memory Boolean | 19.2 | 36 | 36 | 15.2 | 16.2 | 10.8 | 29.25 | 11.25 |
| Test memory bit | 16 | 16 | 16 | 11 | 7.2 | 4.8 | 23 | 14.72 |
| Set/clear memory bit | 4 | 4 | 4 | 3.25 | 2.4 | 1.8 | 6 | 4.5 |
| Test register bit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Set/clear register bit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total memory/time | 2316.2 | 3588 | 3256 | 2879.8 | 2117.6 | 1624.6 | 5389.95 | 1411.39 |
| Relative memory/time | 1.0 | 1.55 | 1.41 | 1.0 | 0.74 | 0.56 | 1.87 | 0.49 |

TABLE 8-8. CPU MEMORY/TIME COMPARISON FOR TYPE L PROGRAMS - FLOATING POINT

| | Memory Requirement (bytes) | | | Execution Time (Microseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SEL | | Interdata | |
| | TI 980 | SEL | Interdata | TI 980 | (900 nsec) | (600 nsec) | 7/32 | 8/32 |
| Single precision load/store | 919.2 | 0 | 0 | 727.7 | 0 | 0 | 0 | 0 |
| Double precision load/store | 4.8 | 1512 | 1584 | 5.8 | 680.4 | 453.6 | 1287 | 495 |
| Single precision add/sub. | 146.4 | 272 | 256 | 115.9 | 224.4/173.4 | 183.6/132.6 | 768/384 | */118.4 |
| Register add/sub. | 8 | 0 | 8 | 5 | 0 | 0 | 44/15 | */4 |
| Double precision add/sub. | 7.2 | 0 | 0 | 8.7 | 0 | 0 | 0 | 0 |
| Single precision multiply | 88.8 | 152 | 152 | 236.8 | 277.4/172.9 | 254.6/150.1 | 1111.5/484.5 | */95 |
| Double precision multiply | 4 | 0 | 0 | 42.7 | 0 | 0 | 0 | 0 |
| Single precision divide | 12 | 20 | 20 | 39.5 | 46.5/24 | 43.5/21 | 242.5/66.25 | */22.25 |
| Double precision divide | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Branch | 240 | 140 | 122.5 | 140 | 63 | 42 | 68.25 | 66.15 |
| Register shift | 66 | 33 | 22 | 57.75 | 19.8 | 13.2 | 30.25 | 10.01 |
| Compare | 82.6 | 136.8 | 122.4 | 64.8 | 57.6 | 39.6 | 108 | 57.6 |
| Conditional skip/branch | 314.4 | 524 | 458.5 | 131 | 235.8 | 157.2 | 262 | 255.45 |
| Register to register | 170 | 255 | 170 | 106.25 | 76.5 | 51 | 85 | 34.85 |
| Add/sub. to memory | 12 | 20 | 20 | 14.5 | 13.5 | 9 | 25 | 10 |
| Register Boolean | 44 | 45 | 30 | 27.5 | 13.5 | 9 | 15 | 6.15 |
| Memory Boolean | 144 | 268 | 268 | 114 | 120.6 | 80.4 | 217.75 | 83.75 |
| Test memory bit | 56 | 56 | 76 | 38.5 | 25.2 | 16.8 | 109.25 | 69.92 |
| Set/clear memory bit | 16 | 16 | 52 | 13 | 9.6 | 7.2 | 78 | 58.63 |
| Test register bit | 10 | 15 | 0 | 6.25 | 4.5 | 3 | 0 | 0 |
| Set/clear register bit | 18 | 27 | 0 | 9 | 8.1 | 5.4 | 0 | 0 |
| Total memory/time | 2363.4 | 3491.8 | 3361.4 | 1904.65 | 1876.4/ 1698.4 | 1369.1/ 1191.1 | 4451.5/ 3235.25 | */ 1387.16 |
| Relative Memory/time | 1.0 | 1.48 | 1.42 | 1.0 | 0.99/0.89 | 0.72/0.63 | 2.34/1.7 | */0.73 |

NOTE: Floating point execution times are given in both Firmware and High Speed Floating Point (HSFP) hardware.

* indicates the operation is not available.

TABLE 8-9. MEMORY/TIME COMPARISON FOR TYPE L PROGRAMS - FIXED POINT ARITHMETIC

| | Memory Requirement (bytes) | | | Execution Time (Microseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SEL | | Interdata | |
| | TI 980 | SEL | Interdata | TI 980 | (900 nsec) | (600 nsec) | 7/32 | 8/32 |
| Single precision load/store | 919.2 | 0 | 0 | 727.7 | 0 | 0 | 0 | 0 |
| Double precision load/store | 4.8 | 1512 | 1584 | 5.8 | 680.4 | 453.6 | 1287 | 495 |
| Single precision add/sub. | 146.4 | 0 | 0 | 115.9 | 0 | 0 | 0 | 0 |
| Register add/sub. | 8 | 12 | 8 | 5 | 3.6 | 2.4 | 4 | 1.64 |
| Double precision add/sub. | 7.2 | 256 | 256 | 8.7 | 115.2 | 76.8 | 208 | 80 |
| Single precision multiply | 88.8 | 0 | 0 | 236.8 | 0 | 0 | 0 | 0 |
| Double precision multiply | 4 | 152 | 152 | 42.7 | 235.6 | 212.8 | 912 | 136.04 |
| Single precision divide | 12 | 0 | 0 | 39.5 | 0 | 0 | 0 | 0 |
| Double precision divide | 0 | 20 | 20 | 0 | 47.5 | 44.5 | 413.75 | 30 |
| Branch | 240 | 140 | 122.5 | 140 | 63 | 42 | 68.25 | 66.15 |
| Register shift | 66 | 99 | 66 | 57.75 | 59.4 | 49.5 | 90.75 | 30.03 |
| Compare | 82.6 | 136.8 | 122.4 | 64.8 | 57.6 | 39.6 | 108 | 57.6 |
| Conditional skip/branch | 314.4 | 524 | 458.5 | 131 | 235.8 | 157.2 | 262 | 255.45 |
| Register to register | 170 | 255 | 170 | 106.25 | 76.5 | 51 | 85 | 34.85 |
| Add/sub. to memory | 12 | 20 | 20 | 14.5 | 13.5 | 9 | 25 | 10 |
| Register Boolean | 44 | 45 | 30 | 27.5 | 13.5 | 9 | 15 | 6.15 |
| Memory Boolean | 144 | 268 | 268 | 114 | 120.6 | 80.4 | 217.75 | 83.75 |
| Test memory bit | 56 | 56 | 76 | 38.5 | 25.2 | 16.8 | 109.25 | 69.92 |
| Set/clear memory bit | 16 | 16 | 52 | 13 | 9.6 | 7.2 | 78 | 58.63 |
| Test register bit | 10 | 15 | 0 | 6.25 | 4.5 | 3 | 0 | 0 |
| Set/clear register bit | 18 | 27 | 0 | 9 | 8.1 | 5.4 | 0 | 0 |
| Total memory/time | 2363.4 | 3553.8 | 3405.4 | 1904.65 | 1769.6 | 1260.2 | 3883.75 | 1415.21 |
| Relative memory/time | 1.0 | 1.5 | 1.44 | 1.0 | 0.93 | 0.66 | 2.04 | 0.74 |

TABLE 8-10. SUMMARY OF CPU MEMORY/TIME COMPARISON

| Computer | Mode | Memory Requirements A-type | Memory Requirements L-type | Execution Times A-type | Execution Times L-type |
|---|---|---|---|---|---|
| TI 980 | Fixed Point | 1.0 | 1.0 | 1.0 | 1.0 |
| SEL with | Floating Point | 1.50 | 1.48 | 0.84 | 0.99 |
| 900 nano seconds | with HSFP | 1.50 | 1.48 | 0.68 | 0.89 |
| Core | Fixed Point | 1.55 | 1.50 | 0.74 | 0.93 |
| SEL with | Floating Point | 1.50 | 1.48 | 0.66 | 0.72 |
| 600 nano-seconds | with HSFP | 1.50 | 1.48 | 0.5 | 0.63 |
| Core | Fixed Point | 1.55 | 1.50 | 0.56 | 0.66 |
| Interdata | Floating Point | 1.36 | 1.42 | 2.42 | 2.34 |
| 7/32 | with HSFP | 1.36 | 1.42 | 1.37 | 1.7 |
| (750 nano-seconds core) | Fixed Point | 1.41 | 1.44 | 1.87 | 2.04 |
| Interdata | Floating Point | 1.36 | 1.42 | N/A | N/A |
| 8/32 | with HSFP | 1.36 | 1.42 | 0.46 | 0.73 |
| (750 nano-seconds core) | Fixed Point | 1.41 | 1.44 | 0.49 | 0.74 |

### 8.3.1.3 Execution Time Estimates

8.3.1.3.1 Simulator Systems. For each of the simulator systems, memory space and execution time estimates were made for the AH-64 based on using the TI980 computer and our knowledge of simulators using that machine. An average instruction execution time of 2.4 microseconds was used to estimate the time for programs that do not yet exist. The results broken up into iteration bands are illustrated in Table 8-11.

The execution times were estimated for each band (50 millisecond, 100 millisecond, etc.) and then normalized to 50 milliseconds as shown in Table 8-17.

The execution times were then estimated for the AH-64 using SEL with both 600 and 900 nanosecond memory and the Interdata 8/32. SEL execution times are for both firmware floating point and high speed floating point hardware. Interdata 8/32 times are for high speed floating point hardware only. The following steps were pursued in compiling the necessary figures:

(a) The various programs were separated into A-type and L-type and the appropriate factor in Tables 8-6 and 8-7 was used to arrive at the new execution time.

(b) The programs were assigned to either CPU A (master) or CPU B (slave) in such a way as to distribute the load evenly and take into account a program's dependence on other programs and local peripherals.

(c) In calculating execution times for SEL without HSFP, A-type programs used floating point while L-type programs used fixed point.

(d) The estimates for line of sight calculations were not included as an algorithm has not yet been worked out. The algorithm will depend on a decision made on the nature of the visual data base. This subroutine is expected to run asynchronously in CPU B (slave).

The results of the execution time comparison are shown in Table 8-13.

8.3.1.3.2 Operating Systems. The overhead imposed by a real time operating system (OS) will depend upon the number of tasks to be scheduled, whether or not they have to be initialized prior to execution, and the number of I/O requests and interrupts. This overhead time can be 100% in a no load situation where the OS is searching for a task to which to transfer control.

TABLE 8-11. MEMORY & EXECUTION TIME ESTIMATES BASED ON TI980

| Program | Memory Estimates (16-Bit Words) | EXECUTION TIME / BAND (ms) 50 ms | 100 ms | 200 ms | 800 ms | Asynchronous 50ms |
|---|---|---|---|---|---|---|
| Engines | 2836 | 1.08 | 1.68 | 6.26 | 1.2 | |
| Ancillaries | 3073 | | 3.81 | 4.0 | 1.92 | 0.4 |
| Instructor Facility | 14000 | 0.4 | | | 6.0 | 1.4 |
| Flight & Motion | 8992 | 31.0 | | | | |
| Radio Aids | 13600 | | 9.5 | | | 0.2 |
| Visual | 3000 | 9.3 | | | | |
| Weapons | 12000 | | 14.4 | | 7.2 | |

TABLE 8-12. NORMALIZED EXECUTION TIMES PER TI980

| PROGRAM | AVERAGE EXECUTION TIME/50 ms |
|---|---|
| Engines | 3.49 |
| Ancillaries | 3.5 |
| Instructor's Facility | 2.4 |
| Flight & Motion | 31.0 |
| Radio Aids | 4.95 |
| Visual | 9.3 |
| Weapons | 15.3 |

TABLE 8-13. CPU EXECUTION TIME COMPARISON — AH-64 SIMULATION PROGRAMS

| | | | | Execution Time (milliseconds) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | with High Speed Floating Point | | | without HSFP | |
| | Program | Type | TI-980 | SEL 900 nsec | SEL 600 nsec | Interdata 8/32 | SEL 900 nsec | SEL 600 nsec |
| CPU | Engines | A | 3.49 | 2.37 | 1.75 | 1.61 | 2.9 | 2.3 |
| 'A' | Flight | A | 31.0 | 21.08 | 15.5 | 14.26 | 26.0 | 20.46 |
| (Master) | Ancillaries | L | 3.5 | 3.12 | 2.21 | 2.56 | 3.3 | 2.3 |
| | Instr. Fac. | L | 2.4 | 2.14 | 1.51 | 1.75 | 2.2 | 1.58 |
| Sub Total | | | | 28.71 | 20.97 | 20.18 | 34.4 | 26.64 |
| CPU | Weapons | L | 15.3 | 13.62 | 9.64 | 11.17 | 14.2 | 10.1 |
| 'B' | Visual | L | 9.3 | 8.28 | 5.86 | 6.79 | 8.65 | 6.14 |
| (Slave) | Radio Aids | L | 4.95 | 4.41 | 3.12 | 3.61 | 4.6 | 3.27 |
| Sub Total | | | | 26.31 | 18.62 | 21.57 | 27.45 | 19.51 |
| | Total Simulation Prog. | | | 55.02 | 39.59 | 41.75 | 61.85 | 46.15 |

NOTE: Line of sight calculations are not included

Where there is only one task which does not request I/O nor any other supervision function, the overhead would be close to 0%, allowing for servicing of clock interrupts only. A realistic OS overhead was arrived at using estimated execution times for basic OS functions, the number of tasks scheduled in each CPU and maximum I/O activity expected. These figures are calculated on the basis of 50 millisecond iteration. The execution times are estimates for SEL (600 nanosecond) and Interdata 8/32. The SEL with 900 nanosecond memory will be 30% slower.

The OS tasks times of the master and slave CPU are listed in Table 8-14. The OS transfer rates are shown in Table 8-15.

These times do not take into consideration the slowing down of the CPU due to memory contention with DMA devices. The impact of memory contention is greater on the Interdata 8/32 than on the SEL. This is as a result of the difference in machine architecture and memory bus controller. The net effect on the simulator is not expected to be great in either case.

It should be noted that the SEL computer does not interrupt after character or byte oriented devices and therefore will not require the 2.4 millisecond for interrupt servicing.

TABLE 8-14. CPU TASKS

Master CPU:

| | | |
|---|---|---|
| 13 tasks to be scheduled @ 300 μsec | = | 3.9 msec |
| 5 I/O requests (Table 8-15) @ 1 msec | = | 5 msec |
| 1 request to initiate simulator interface | = | 250 μsec |
| 6 interrupts at end of I/O transfer @ 50 μsec | = | 300 μsec |
| 150 interrupts from character oriented devices (Table 8-15) @ 16 μsec | = | 2.4 msec |
| | | 11.85 msec |

Slave CPU:

| | | |
|---|---|---|
| 10 tasks to be scheduled @ 300 μsec | = | 3 msec |
| 2 request to visual system @ 1 msec | = | 2 msec |
| 2 request to FHD @ 1 msec | = | 2 msec |
| 4 interrupts at end of I/O transfer @ 50 μsec | = | 200 μsec |
| | | 7.2 msec |

TABLE 8-15. TITLE OPERATING SYSTEM TRANSFER RATES

| Device | Transfer rate bytes/sec | Transfer Size bytes | Request Per Sec | Request Per 50 msec | Bytes Transferred per 50 msec |
|---|---|---|---|---|---|
| Console | 30 | 10 | 3.3 | | |
| CRT | 960 | 40 | 24 | | |
| Card Reader | 400 | 80 | 5 | 2 | 150 |
| Line Printer | 660 | 132 | 5 | | |
| Plotter | 960 | 1000 | 1 | | |
| Disc | | One transfer was assumed per 50 msec for each of these | | 1 | |
| MT | | | | 1 | |
| Display | | | | 1 | |

NOTE: These rates can be considered peak loading I/O request & transfer rates for CPU A.

8.3.1.3.3 Combined Time Estimates. The results are summarized for SEL (600 and 900 nsec) and Interdata 8/32 in Table 8-16. This table shows that the SEL (600 nanoseconds) with HSFP can meet the requirement of 100% spare, while the Interdata 8/32 at 94% and the SEL (600 nsec) without HSFP at 80% fall just short of this requirement. The SEL (900 nsec) with 42% and 27% spare can be ruled out as a candidate for this application. Also, the values in Table 8-16 clearly justify the choice of a multi-CPU configuration.

These calculations do not take into account the requirements of the line of sight calculations which run asynchronously in CPU 'B' and the extent of which cannot presently be estimated. The background task's execution time has also not been considered as it is expected to use spare time, i.e., that time not used by OS or simulation tasks.

TABLE 8-16. CPU EXECUTION TIME COMPARISON FOR TOTAL AH-64 SIMULATOR PROGRAMS

| | Execution Time (milliseconds) | | | | |
|---|---|---|---|---|---|
| | with HSFP Hardware | | | without HSFP | |
| | SEL 900 nsec | SEL 600 nsec | Interdata 8/32 | SEL 900 nsec | SEL 600 nsec |
| CPU 'A' (Master) | | | | | |
| Operating System | 12.29 | 9.45 | 11.85 | 12.29 | 9.45 |
| Simulation Prog. | 28.71 | 20.97 | 20.18 | 34.4 | 26.64 |
| CPU 'B' (Slave) | | | | | |
| Operating System | 9.4 | 7.2 | 7.2 | 9.4 | 7.2 |
| Simulation Prog. | 26.31 | 18.62 | 21.57 | 27.45 | 19.51 |
| Time Required | 76.71 | 56.24 | 60.8 | 83.54 | 62.8 |
| Spare Time | 23.29 | 43.76 | 39.2 | 16.46 | 37.2 |
| % Spare | 42.3 | 110.5 | 93.9 | 26.6 | 80.6 |

NOTE: $\% \text{ Spare} = \dfrac{\text{Spare time (Table 8-16)}}{\text{Simulation Prog. time (Table 8-13)}} \times 100$

8.3.1.4 Memory Usage Estimates. Using the estimated TI980 AH-64 memory requirements of Table 8-11 and the SEL and Interdata instruction memory requirements in Table 8-10, it is possible to estimate the SEL and Interdata simulation system memory requirements for the AH-64 (Table 8-17).

TABLE 8-17. SIMULATION PROGRAM MEMORY REQUIREMENTS

| | Prog type | Memory Requirements (K bytes) | |
|---|---|---|---|
| | | SEL | Interdata |
| CPU 'A' | | | |
| Engines | A | 8.5 | 7.7 |
| Flight & Motion | A | 30.0 | 24.5 |
| Ancillaries | L | 9.1 | 8.7 |
| Instructor's Facility | L | 41.5 | 39.8 |
| TOTAL CPU 'A' | | 89.1 | 80.7 |
| Weapons | L | 35.5 | 34.1 |
| Visual | L | 8.9 | 8.5 |
| Radio Aids | L | 20.1 | 19.3 |
| TOTAL CPU 'B' | | 64.5 | 61.9 |

The memory requirements of the operating system is estimated at 64K bytes for CPU 'A' and 40K bytes in CPU 'B' plus an additional 48K bytes in CPU 'A' for background activity.

The shared memory containing the cross X-reference data is estimated at 20K bytes, radio stations data 2K bytes, Visual Safety program data base 7K bytes and a buffer area for CPU to CPU transfer 2K bytes. A total of 31K bytes are required for shared memory.

Table 8-18 summarizes the memory requirements for the AH-64 flight and weapons trainer. With the configuration of 262 Kbytes to each CPU and 65K bytes to shared memory, the 100% spare requirement can be met for both SEL and Interdata machines.

TABLE 8-18. BREAKDOWN OF TOTAL MEMORY REQUIREMENTS AND AVAILABILITY (K bytes)

| | SEL | Interdata | Available Memory |
|---|---|---|---|
| CPU 'A' (Master) | | | |
| Simulation | 89.1 | 80.7 | |
| OS | 64.0 | 64.0 | |
| Background | 48.0 | 48.0 | |
| TOTAL CPU 'A' | 185.1 | 176.7 | 256 |
| CPU 'B' (slave) | | | |
| Simulation | 64.5 | 61.9 | |
| OS | 48.0 | 48.0 | |
| TOTAL CPU 'B' | 112.5 | 109.9 | 256 |
| Shared Memory | 31.0 | 31.0 | 65 |
| TOTAL | 344.6 | 333.6 | 577 |
| Required Spare | 184.6 | 172.7 | |
| Available Spare | 232.4 | 243.4 | |
| % Spare | 125.9 | 140.1 | |

8.3.2 Memory Type Analysis

8.3.2.1 General. Core memory's twenty years of domination over computer memory has recently been challenged by metal oxide semiconductor P-Channel 1 K dynamic random access memory (MOS RAM) and now by the 4K static MOS RAM.

In the past, various attempts were made to replace core memory as shown by a list below:

- Plate wire
- Magnetic thin film
- Braided wire
- Plated glass rods
- Thick film
- Various semiconductor technologies

MOS memory technology has proven itself at least as good as core, if not better, in most areas. A comparison of technologies will cover the following areas:

- Reliability
- Cost
- Speed
- Volatility
- Environmental tolerance

8.3.2.2 Reliability. Reliability is achieved largely through good design practices and production control by the manufacturer. However, inherent characteristics in each technology will play a major role in determining what reliability can be achieved. These are: parts count, parts reliability, mechanical assemblies and number of levels of translation.

With fewer parts, there are fewer things that can go wrong. The core memory board is more complex and has greater number of parts than the equivalent MOS memory.

Reliability predictions using expected failure rates of individual parts can be done using the USAF Rome Air Development Centre (RADC) method. Assuming that the designer stays below the 50% power and voltage stress levels, a 16 K-word x 16-bit core array with associated circuitry should demonstrate a failure rate of about 9%/1000 hrs. Reliability of a similar semiconductor array should demonstrate a failure of about 8%/1000 hrs. Comparison of smaller memory sizes would be favorable to semiconductor memory, however, on larger memories core should have the edge because the MTBF of semiconductor memories is more directly related to the number of components (RAM chips) which is a function of memory size. However, availability on semiconductor memory can be increased using error checking and correction logic.

Core stacks, being complex mechanical packages, are more prone to mechanical failures.

The number of level translations are important because this is where significant part stresses are encountered as well as transient noise. Three wire/3D core require external level translation for X-driver, Y-driver, inhibit driver and sense amplifier. On semiconductor memories the level translations are done within the chip, hence they are reduced in complexity and are highly immune to noise.

8.3.2.3 Cost. The cost of both core and semiconductor memories has decreased in recent years. The price of semiconductor memory, however, has decreased at a much faster rate. Currently the price of semiconductor memory is very close to that of core memory.

Further cost reduction of core is limited by technology, the physical size of the core, human factors and labor cost. Core technology has bottomed out with the 18 mils ferrite core. Smaller core is possible but creates difficulties for current stringing techniques. The stringing of cores is done manually and as in every field, labor costs are rising. The most likely area for cost reduction is in the overhead circuitry associated with a core stack.

The outlook for semiconductors, on the other hand, is optimistic. The technology is making progress in overcoming size and cost limitations. The size is currently limited by optical resolution of the photo-litho-graphic processes. A factor which adds greatly to the cost of semiconductor memory is that of battery backup units.

The cost of using semiconductor memories is potentially lower than that of core. Semiconductor memories consume less power and the boards are theoretically easier to repair, i.e., a RAM chip as opposed to a core stack. It seems however that a significant number of core failures are due to the overhead circuitry.

8.3.2.4 High Speed. Core memory has to be switched in order to be read, this is a destructive read requiring that the contents be restored. Semiconductor memory is used by sensing the presence or absence of charge by a FET, this readout is nondestructive.

Although semiconductor access speeds are only marginally better than those of core memories, they are open to significant improvement whereas core is not.

The reduction of level translation and simplification of timing techniques would improve the access time.

8.3.2.5 Volatility. The area in which core memory is clearly superior to semiconductor is its nonvolatility. Once the power to the memory is lost, semiconductor memory will lose the information stored in it. Core memory, on the other hand, will retain the information indefinitely.

Various forms of battery backup units have been made available to save the contents of the voltaile semiconductor memory. The battery backup units serve only for short term data retention, meant to provide power to memory during power failures of up to a few hours in duration.

Memory retention time can be increased by either reducing the power consumption of the memory or by using a larger battery. The first alternative is a long term goal of memory designers and is not presently available. No large nickel cadium battery exists that will guarantee that it can become operable and can take charge within a reasonable period of time. Using parallel nickel cadium batteries increases the cost of the memory significantly.

In simulator application, long term memory retention is unnecessary as an interruption of an hour or two would necessitate the restarting or repositioning of the training exercise by reloading from a mass storage device.

8.3.2.6 Environmental Tolerance. Most minicomputers require an operating temperature range of $0^{o}$ to $50^{o}C$. This temperature range is well within the tolerances of core and MOS memories. However, core memory dissipates more heat and therefore requires a better cooling system than MOS memory.

Humidity has a greater effect on a core stack than it will on a sealed RAM IC. Good manfuacturing practices are required in both cases to reduce the possible damage caused by humidity and organic growth.

Semiconductor memories have a greater tolerance to vibration and shock than a core stack.

8.3.2.7 Memory Type Summary. To summarize, it is clear that semiconductor memories based on 4K MOS RAM are well on their way to gaining prominence over core. While semiconductor technology is improving by leaps and bounds, core memories have seen little inovation in recent years. The number of core suppliers is decreasing and core has not made its mark in fields such as computer terminals, calculators and micro computer systems. Large minicomputers, however, have stayed with core or will offer a choice of core or semiconductor memories.

The probable reason for the continued use of core by large minicomputers is:

(a) The heavy investments in developing and manufacturing core based systems made the cost/bit of early 1K MOS RAM technology unattractive.

(b) The complexity of timing requirements of these early RAMs did not meet the reliability standards of the computer industry.

(c) The semiconductor technology was not stable, as has been evident since the release of these minicomputers.

Although many of the minicomputer manufacturers are looking at MOS memory for inclusion in their product line, current 32-bit minicomputers offer only core memory. CAE will give further consideration to MOS memory when it becomes available on 32-bit machines.

8.3.3 Mass Storage Devices. Mass storage devices have formed a principal part of simulated and control systems supplied by CAE for a number of years.

The three mass storage devices which are presently included in the AH-64 computer system configuration are: a Moving Head Disc (MHD), Magnetic Tape (MT) transport, and a Fixed Head Disc (FHD). These devices, incorporated on the AH-64 will be, wherever possible, commercially available devices offered by the computer vendor and will always adhere to the industry's specifications governing the magnetic media, i.e., disc packs and magnetic tape reels. Recommended characteristics for each device can be produced from a knowledge of the simulator environment.

8.3.3.1 Moving Head Disc. The recommended characteristics for the MHD configuration are large capacity, high performance, removable pack, random access storage incorporating the following features:

(a) MHD drive operated with a spindle speed of 3600 rpm resulting in an average rotational latency of 8.3 milliseconds.

(b) Head positioning is performed by a closed loop proportional servo system driving a voice coil head actuator mechanism. Access time ranging from 7 to 55 milliseconds for track to track seek with an average access time of 30 milliseconds.

(c) Head positioning information is permanently recorded on one of the recording surfaces.

(d) The transfer rate is 1.2 megabytes per second minimum.

(e) The disc drive is capable of detecting seek errors, track position errors, loss of rotational speed error or loss of voltage error.

(f) Heads which will retract when loss of speed or voltage errors are detected in order to prevent damage to the recording surface.

(g) Moving Head Disc interfaced to CPU 'A' through an MHD controller. This controller will be capable of controlling up to four disc drives and capable of detecting and correcting read/write errors through the use of an error detection code.

8.3.3.1.1 Disc Activity Estimates. During the simulation process the following disc requests are expected to take place based on present disc utilization on CAE flight simulators and a disc system as previously specified.

(a) A sequential search of the radio station data file every time the aircraft travels 10 miles. Ten transfers of 1500 bytes are made each time.

(b) A request for a particular station at any time. Typically twice during a training exercise.

(c) A CRT page requirement to appear on the display within two seconds of being requested. This can consist of seven transfers, the largest being 500 bytes.

(d) Record and playback, maneuver demonstration and unusual attitudes are all mutually exclusive and require a transfer of 600 bytes at 800 millisecond intervals.

(e) Flyout and store recall are also mutually exclusive and occur once every 10 seconds during record and requires two transfers of 5600 bytes.

(f) Assuming that the visual data base for a CCTV/Model Board safety program is located on the MHD, a 3200 byte transfer may be required at 2.5 to 10 second intervals.

In order to determine the maximum disc usage during simulation, consider a two second time frame during which every type of disc request occurs. Table 8-19 gives the breakdown by request type.

TABLE 8-19. MAXIMUM DISC ACTIVITY DURING A TWO SECOND INTERVAL

| | # of transfers | # of bytes transferred |
|---|---|---|
| Radio station scan | 10 | 1400 |
| Radio station select | 1 | 32 |
| Record and playback | 2.5 | 1500 |
| CRT page request | 7 | 1260 |
| Flyout | 2 | 5600 |
| Visual safety | 1 | 3200 |
| | 23.5 | 12992 |

A total of 23.5 requests at an average of 38.3 milliseconds per request gives a total of 900.1 milliseconds of seek and repositioning time. A total transfer of 12992 bytes at a rate of 1.2K bytes/second will take 10.8 milliseconds. This means that during a two second interval, the disc would be busy 910.9 milliseconds or 45% of the time.

More conservative figures which reflect a realistic situation are presented in Table 8-20. The interval is 10 minutes.

Total seek time in 10 minutes is estimated at 35 seconds or 6%. Transfer time during the 10 minutes of simulation is 0.7 second or 1.2% of the total time. The longest estimated transfer is 41.0 milliseconds, and represents the longest delay in servicing a higher priority transfer request.

TABLE 8-20. DISC ACTIVITY DURING 10 MINUTES

| | Request Interval | # of transfers | # of bytes transferred |
|---|---|---|---|
| Radio station scan | 3 min | 33 | 46200 |
| Radio station select | 10 min | 1 | 32 |
| Record and playback | 800 msec | 750 | 450000 |
| CRT page request | 10 min | 7 | 1260 |
| Flyout | 10 sec | 120 | 336000 |
| Visual safety | 5 sec | 2 | 6400 |
| | | 913 | 839892 |

8.3.3.1.2 Disc Space Requirements. The disc space requirements can be categorized as permanent data files, work files, program files and load modules.

(a) The permanent data file requirements estimated for the AH-64 using previous simulator requirements are as follows:

| | | | |
|---|---|---|---|
| . CRT page file (500 pages) | = | 2M | bytes |
| . Maneuver demonstration (300 min) | = | 13.5M | bytes |
| . Unusual Attitude (100 sec) | = | 150K | bytes |
| . Radio station data (500 stations) | = | 16K | bytes |
| . Radio station description | = | 16K | bytes |
| . Visual safety data base | = | 4M | bytes |
| | | 19.68 | bytes |

(b) The work file requirements:

| | | | |
|---|---|---|---|
| Record/playback (30 min) | = | 1.35M | bytes |
| Flyout | = | 1.13M | bytes |
| Store/recall | = | 50K | bytes |
| | | 2.53M | bytes |

(c) In order to estimate the disc requirements for program files, the requirements of an existing CH-47 simulator were used. It was found that in order to support 97.1 bytes of loadable programs, it was necessary to have on disc 138.9K bytes of object files and 1,553.7K bytes of source files. This is a ratio of 1:1.43 for object and 1:16 for source.

A breakdown of the various loadable programs on the system is found in Table 8-21.

TABLE 8-21. PROGRAM FILE DISC REQUIREMENTS

| Program | Program size bytes | Object required (K bytes) | Source required (K bytes) |
|---|---|---|---|
| OS CPU A | 64 | 91.5 | - |
| OS CPU B | 40 | 57.2 | - |
| Assembler | 48 | 68.6 | - |
| FORTRAN | 48 | 68.6 | - |
| Linking loader | 48 | 68.6 | - |
| editor | 48 | 68.6 | - |
| debug | 48 | 68.6 | - |
| (5) misc. utilities | 240 | 343.2 | - |
| Simulation programs | 200 | 286 | 3200 |
| | | 1121.1 | 3200 |

As the source of the operating system and background programs are not normally required during simulation, no disc space was allotted to them. These and the source of previous revisions of simulator programs can be loaded from the magnetic tape when needed for updating.

(d) The size of load modules was assumed to be equal to the memory space they occupy. Assuming three revisions of the simulator load module are kept, disc area requirement for load modules is as follows:

| | | | |
|---|---|---|---|
| . OS for CPU A and B | = | 104K | bytes |
| . Background utilities | = | 480K | bytes |
| . Simulation program (x3) | = | 600K | bytes |
| | | 1184K | bytes |

Total disc requirements are as follows:

| | | | |
|---|---|---|---|
| . Permanent data files | = | 19.68M | bytes |
| . Work files | = | 2.53M | bytes |
| . Program files object | = | 1.12M | bytes |
| . Program files source | = | 3.2 M | bytes |
| . Load modules | = | 1.18M | bytes |
| | | 27.7M | bytes |

8.3.3.2 Magnetic Tape Transport. The recommended characteristics of the MT Transport to be used in the AH-64 FWS can be itemized as follows:

. Industry compatible MT Transport to provide portability other computer systems.

. Capable of recording on nine tracks at a speed of 45 ips at a recording density of 800 bpi. Standard 10½ inch or 2400 foot reels of magnetic tape.

. NRZI recording mode.

. A rewinding speed of 150 ips.

The total capacity of a 2400 foot reel is 23M bytes: that is, without taking into account interrecord gaps. If each record is blocked at 3000 bytes per record, the MT will have a total capacity of 19.2M bytes. This is sufficient to contain the largest file 13.5M bytes (maneuver demonstration) or a copy of all source and object programs for OS and simulator programs 12.0M bytes.

8.3.3.3 Fixed Head Disc. The use of an FHD depends heavily on the data base(s) requirements for the visual safety program and the line of sight calculations.

The advantage of using an FHD over any other magnetic mass storage media is its fast access time and higher reliability. FHD units such as the DDC 6000 series offer an average access time of 8.5 milliseconds and have storage capability of 4.6 to 9.2M bytes.

As mentioned previously, the visual safety program may require four Mbytes of storage. This would provide two copies of the data base for redundancy. In the event of a CGI system, the size of the CGI visual data base is not known but it would be desirable to have a copy of it available to the 'line of sight' subroutine in CPU 'B'.

A combined use of FHD and an MHD can also be considered in order to give the best compromise between storage needs and access speed.

8.3.4 Programmer/Operator Peripherals. The peripherals suggested as part of the computer module configuration in paragraph 8.2 are not used during the training exercise but are provided only for system control and software maintenance.

The peripherals recommended are consoles, a line printer, card reader and a CRT. These devices will account for only a very small portion of the computer I/O load. The peripherals recommended will be chosen from standard equipment offered by the computer vendor, where possible.

8.3.4.1 Console(s). The console function is to provide a means of communication with the computer operating system and is intended purely for low volume, low speed I/O.

The recommended console will have a keyboard and a printer with the following features:

- Printing speed of 10 - 30 characters per second.
- Capable of printing 72 characters per line on multiple part paper.
- Standard ASCII character set.

Interfacing to the computer will be via current loop or equivalent.

8.3.4.2 Line Printer. The presence of a line printer is essential on any machine for which program assemblies are proposed and as such is necessary in the AH-64 FWS.

The recommended type of line printer is a drum type impact printer with the following capabilities:

- . Capable of printing 132 character/line at a rate of 300 LPM.
- . 64 ASCII character subset.
- . Printing on standard 8-1/2" by 11" fanfold paper with legibility on one to six copies.
- . Free standing printer with an acoustic cover to reduce noise.
- . The switches and illuminators should include ON/OFF, paper step, top of form, paper slew, and alarm.
- . The interface to the computer will be vendor supplied.

8.3.4.3 Card Reader. The recommended characteristics for a card reader are a reliable device capable of reading standard 80-column Hollerith encoded cards at a rate of 300 cpm. Both hopper and stacker should have a capacity of 500 cards. The interface to the computer will be a standard vendor product.

8.3.4.4 CRT. The function of the alphanumeric keyboard/CRT is to provide high speed display and data entry. The recommended alphanumeric keyboard/CRT characteristics are as follows and should allow easy selection from vendor supplies:

- . Keyboard with a complete 64 alphanumeric character subset of the USA SII standard with the necessary function keys.
- . CRT display screen with a capacity of 1920 characters (24 x 80). Characters are flicker free, and have a high resolution.
- . The recommended interface to the computer is an RS-232C type of unit providing half or full duplex transmission at selectable band rates (110 to 9600).

8.3.5 Instructor Facility. The Instructor Facility proposed in Section 7 consists of two types of units: graphic displays and a hardcopy unit. The bulk of I/O activity from this area will be updated to the displays; a 40 byte transfer every 100 milliseconds. A full CRT page will be shown infrequently but involves the transfer of 1000-2000 bytes. A request for hardcopy requires that the refresh memory in the display be read into the computer memory and sent to the hardcopy device line by line.

8.3.5.1 Graphic Display. The recommended graphic display system of the instructor facility is driven by one 'Graphic 7' Display Controller (Sanders). Four displays will be driven by this controller. See Figure 8-2. Further description of the 'Graphic 7' can be found in Appendix E. Interfacing the Graphic 7 to the computer will be done via a parallel interface supplied by Sanders and either a high speed data interface from SEL, or a Universal Logic Interface and a selector channel (SELCH) from interdata.

The Graphic Display Controller has a maximum transfer rate of 1 M byte/second.

8.3.5.2 Hardcopy Unit. The hardcopy unit will be an electrostatic printer/plotter as described in paragraph 7.4.6.4. I/O requests will be made to it one line at a time over a serial link.

8.3.6 Simulator Interface

8.3.6.1 General. The simulator interface subsystem provides the means whereby several input and output elements of the trainer module may be interfaced with a DMA bus in the master computer. A block diagram of a typical interface system is shown in Figure 8-3.

Functional modules provide the interface with the different elements of a simulator: digital and analog input and output; synchro inputs and outputs. The modules are housed in interface chassis linked to the computer interface controller via a differential signal, parity line, data acquisition and control bus providing high noise immunity and versatile system configuration. The positioning of the functional interface chassis may be random throughout the system at distances of up to 1500 feet from the computer.

The interface described in this section is a recent CAE development incorporating high performance low power Schottky TTL and CMOS integrated circuits in the digital, analog and synchro input/output design. Hardware built-in test features coupled with on-line and off-line software diagnostics provide a highly reliable and easily maintainable interface system.

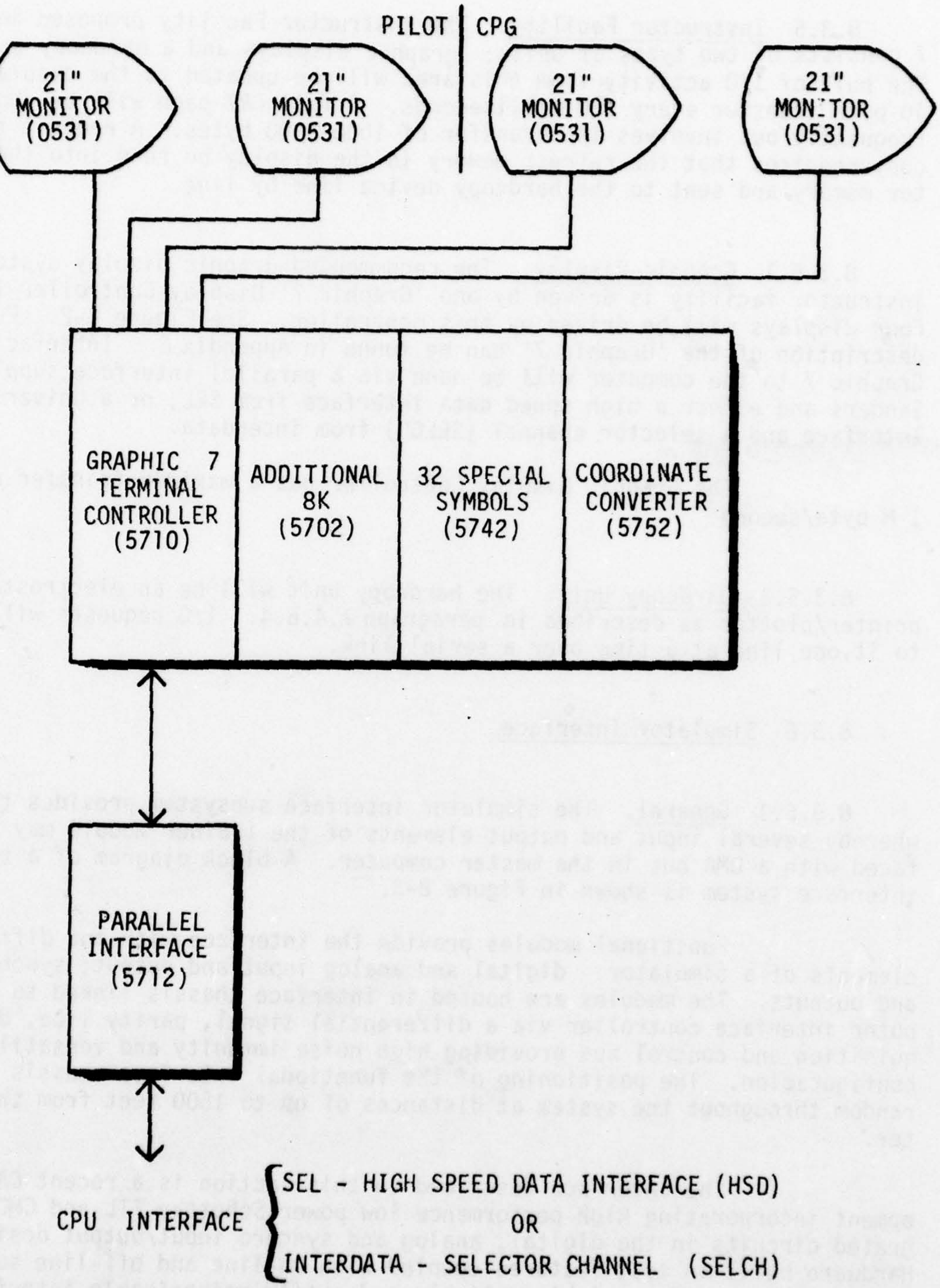



Figure 8-2. Sanders Graphic 7 Configuration

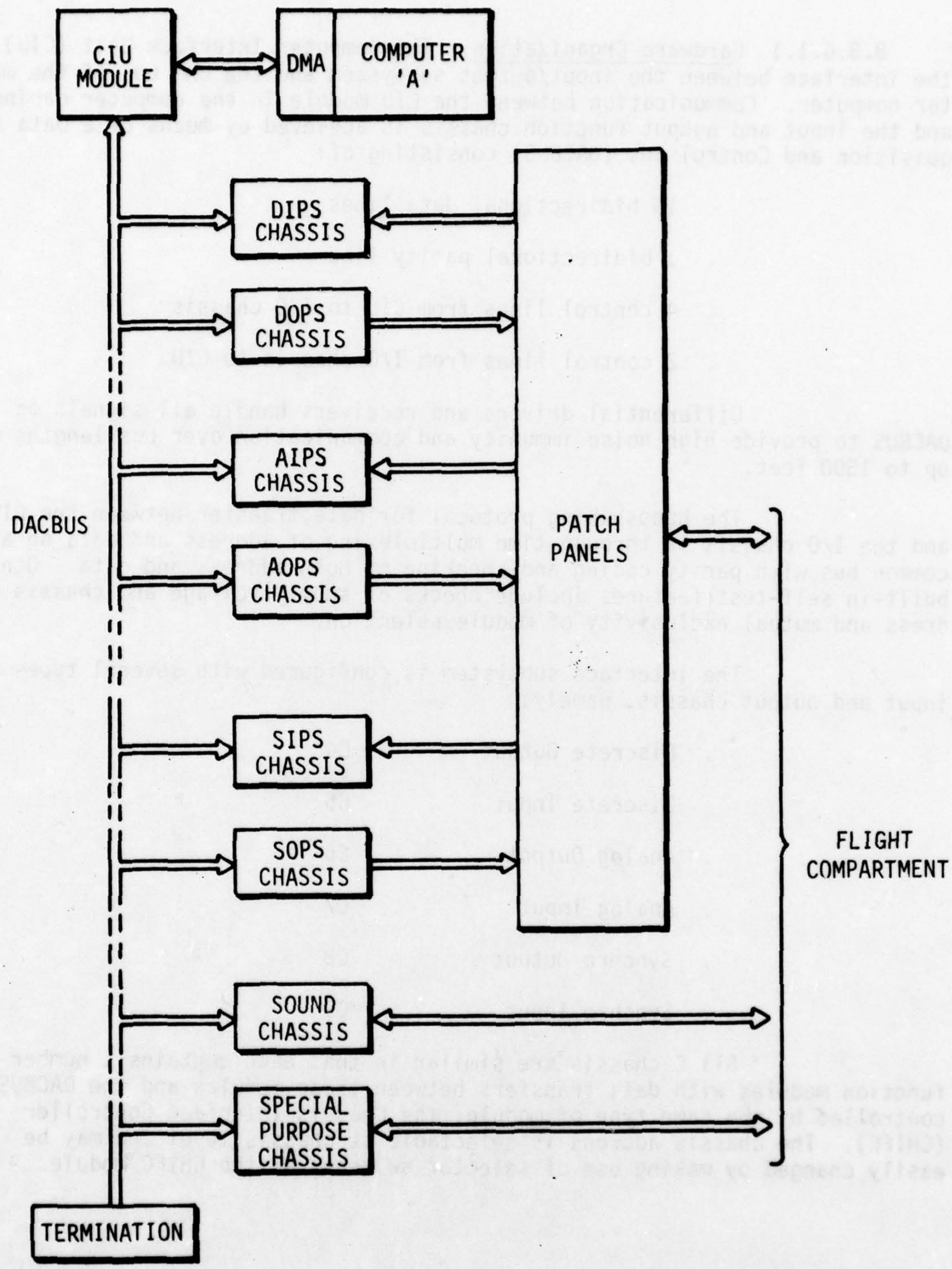



Figure 8-3. Interface System Block Diagram

8.3.6.1.1 Hardware Organization. The Computer Interface Unit (CIU) is the interface between the input/output subsystem and the DMA bus of the master computer. Communication between the CIU module in the computer cabinet and the input and output function chassis is achieved by means of a Data Acquisition and Control Bus (DACBUS) consisting of:

- 16 bidirectional data lines
- 1 bidirectional parity line
- 4 control lines from CIU to I/O chassis
- 2 control lines from I/O chassis to CIU

Differential drivers and receivers handle all signals on the DACBUS to provide high noise immunity and communication over bus lengths of up to 1500 feet.

The handshaking protocol for data transfer between the CIU and the I/O chassis is through time multiplexing of address and data on a common bus with parity coding and checking of both address and data. Other built-in self-test features include checks of supply voltage and chassis address and mutual exclusivity of module selection.

The interface subsystem is configured with several types of input and output chassis, namely:

| | |
|---|---|
| . Discrete Output | C4 |
| . Discrete Input | C5 |
| . Analog Output | C6 |
| . Analog Input | C7 |
| . Synchro Output | C8 |
| . Synchro Input | C9 |

All C chassis are similar in that each contains a number of function modules with data transfers between these modules and the DACBUS controlled by the same type of module; the Chassis Interface Controller (CHIFC). The chassis address is selectable at chassis level and may be easily changed by making use of selector switches on the CHIFC module.

8.3.6.1.2 Interface Address Structure. All elements in the simulator I/O interface system can be resolved into the four basic categories of analog inputs and outputs and discrete inputs and outputs. The address structure is word oriented with each analog input or output channel identified by a single word address and each group of 16 discrete inputs or outputs also identified by a single word address.

The I/O system uses a 16-bit address word of which 13 bits are used for word addressing; thus, 8192 possible addresses exist in the system, 0000 to hexadecimal 1FFF. The three remaining bits of the address word are used for testing and control functions, e.g.:

- For analog inputs, select the gain of the amplifier
- For discrete inputs, transmit the complement of the data word
- For the CHIFC module, transmit a status word

The various analog input/output and discrete input/output addresses may be interlaced within the overall field 0000 to hexadecimal 1FFF.

The 13-bit word address is generally divided into three fields:

- Chassis Address Field
- Module (in chassis) Address Field
- Subword (in module) Address Field

The number of bits in these fields is variable depending upon the word packaging density of the function modules.

8.3.6.2 Standard Interface Assemblies

(a) Computer Interface Unit (CIU). The CIU modules, located in the I/O chassis in the computer cabinet, interface the DACBUS with the DMA bus of the computer. All communication between the I/O interface and the processor takes place through CIU using an I/O instruction.

(b) Discrete Inputs Module (DIPS). Each DIPS module senses the status of 32 digital inputs, contact, closure type, and produces one of two 16-bit data words on command. The inputs are low pass filtered, to eliminate contact bounce noise; and overvoltage protected, to protect from the application of 120 Vac.

(c) Discrete Outputs Module (DOPS). The DOPS module accepts a 16-bit data word from the CIU module, via the DACBUS, and the CHIFC module. The 16-bit word is stored in a register and used to drive 16 mercury-wetted contact relays.

(d) Analog Outputs Module (AOPS). Each AOPS module will provide eight analog output channels with ±10 Vdc output voltage range. The module will store a 12-bit output data word in one of eight registers as selected by the address word. Each register drives a monolithic digital to analog converter integrated circuit. The analog output is buffered and filtered.

(e) Analog Inputs Module (AIPS). Each AIPS module handles 16 differential input channels in the range 0 to ±10 volts. The selected channel is switched through an analog multiplexer to the analog to digital converter (ADC) in the ADC module. After the signal has been given time to stabilize, it is converted to a digital signal. The CIU module is informed through the CHIFC module that the conversion is complete, and is then able to read the digitized voltage.

(f) Synchro Outputs (SOPS). Each SOPS module produces two outputs, each of which is the result of multiplying a 400 Hz ac reference signal by the amplitude defined by a 12-bit (11 bits plus sign) data word. The module stores the 12-bit output data word in one of two registers as selected by the address word. Each register drives a monolithic multiplying digital to analog converter integrated circuit.

A gain potentiometer is provided for each output channel. These are adjusted such that, for similar digital inputs, the outputs of each channel are identical in amplitude and phase.

If one or both of the outputs are short-circuited, a current limiting circuit will operate when the total rms current output of the module exceeds 1 ampere.

(g) Synchro Inputs (SIPS). The SIPS module is capable of converting two pairs of synchro inputs to digital values. The module contains two Scott-T transformers so that synchro inputs may be fed directly to the PCB. Each resolver signal derived from the Scott-T transformers is sampled 16 times over 1 cycle of the reference 400 Hz waveform.

Each pair of digital outputs will then be proportional to the sine and cosine of the synchro angle of that channel. When the ratio of these outputs is calculated in program, the synchro angle can be extracted.

8.3.6.2.1 Other Interface Chassis. In addition to the standard interface, chassis and modules may be required in order to provide drive signals for original aircraft equipment not electrically compatible with the standard interface chassis. Analog equipment shall be provided for in the sound system, audio system, control loading system and motion system.

In the AH-64 simulator, special interface chassis will be required for the electronic attitude indicator, doppler control panel display, radar warning display and audio, pilot and CPG helmet display, gunner head-up video/status display, gunner direct view/video head-down display, and the fire control computer.

8.3.6.3 Interfacing to Aircraft Multiplex Data Bus. There is a requirement to interface to simulator equipment serviced via a multiplex data bus as on the aircraft. The equipment involved is studied further in Section 4 and includes the following:

. Fire control computer

. Lightweight doppler navigation system

. Target acquisition designation system

. Electronic attitude direction indicator

. Integrated helmet and display sight system

A diagram showing the interfacing structure between the FCC and other equipment is shown in Figure 8-4.

The interfacing of the DACBUS to the multiplex data bus as defined by MIL-STD-1553 may be done in either of two ways.

(a) For each simulated airborne subsystem a serial digital interface will be plugged into the DACBUS in place of original parts. This interface will handle all protocol with Remote Terminal (RT) and buffer the full message. (Figure 8-5.)

(b) A special chassis will plug into the DACBUS as one device but will appear to the multiplex data bus controller (FCC) as many RTs. This alternative would also need to buffer all messages to and from the multiplex data bus. (Figure 8-6.)

The first alternative would be the least expensive and neater to implement for a reasonable number of simulated subsystems and would interfere the least with existing multiplex data bus protocol.

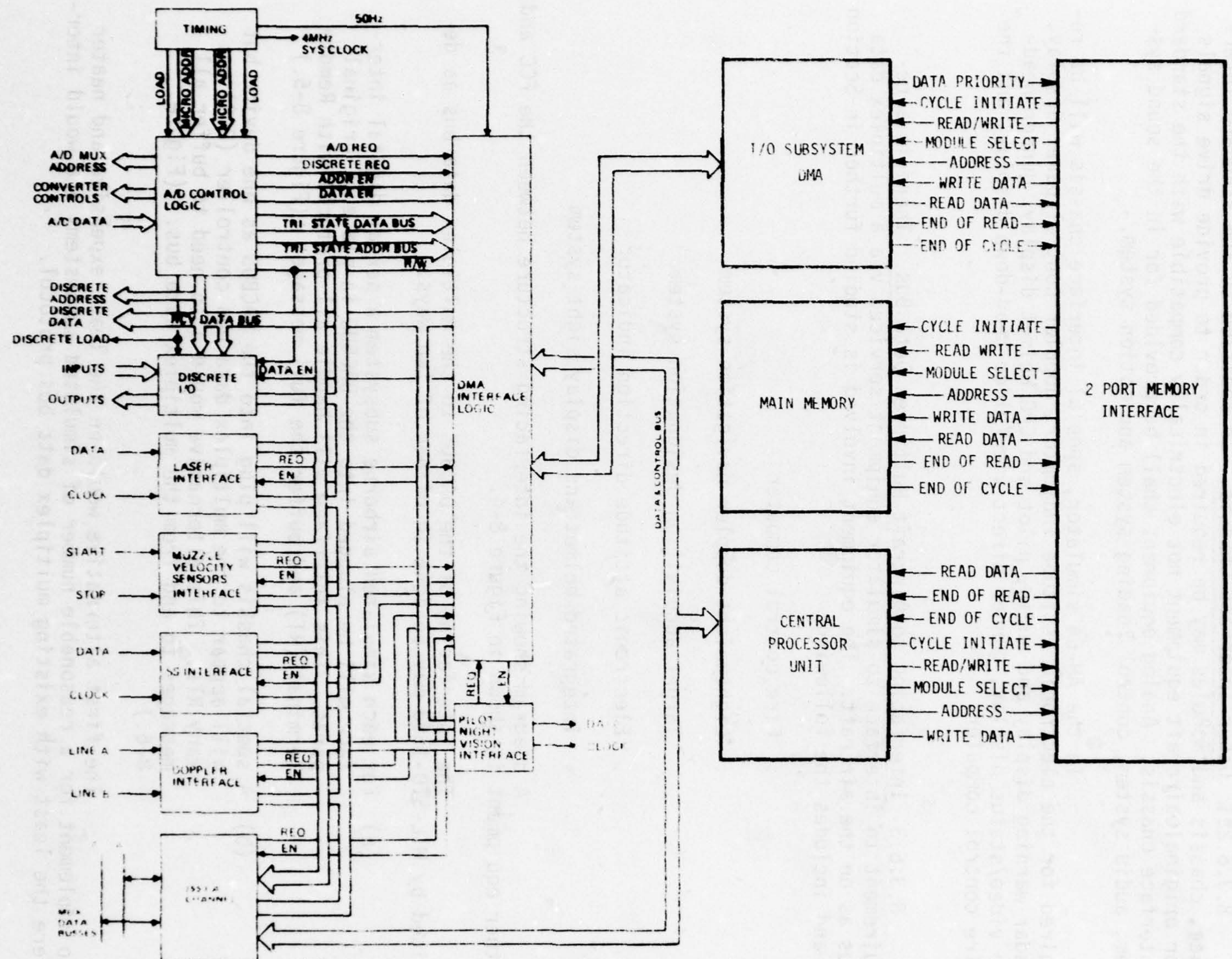



Figure 8-4. Fire Control Computer Interfacing Structure

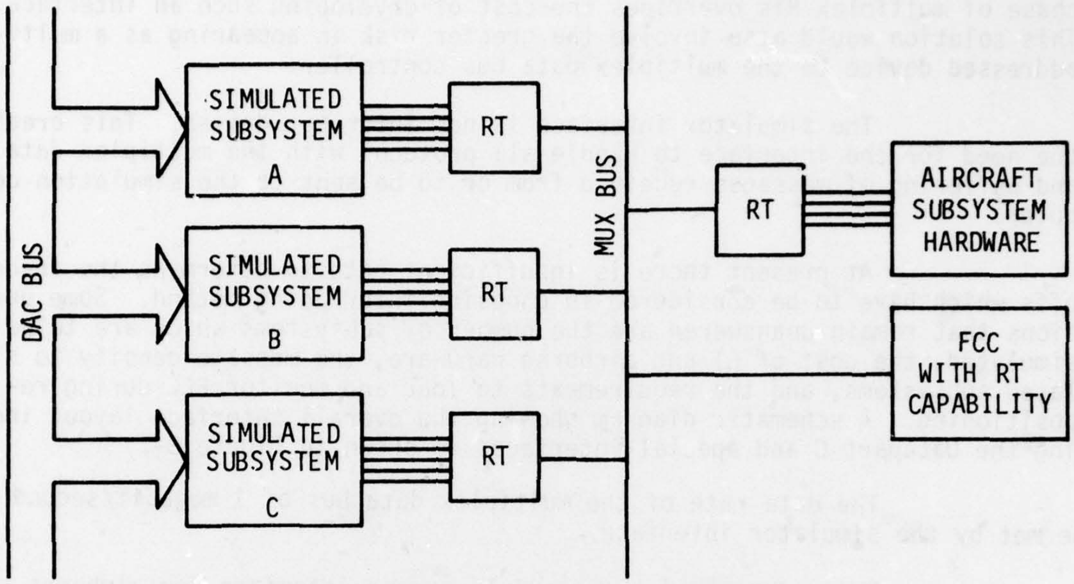



Figure 8-5. Alternative A for Multiplex Interface

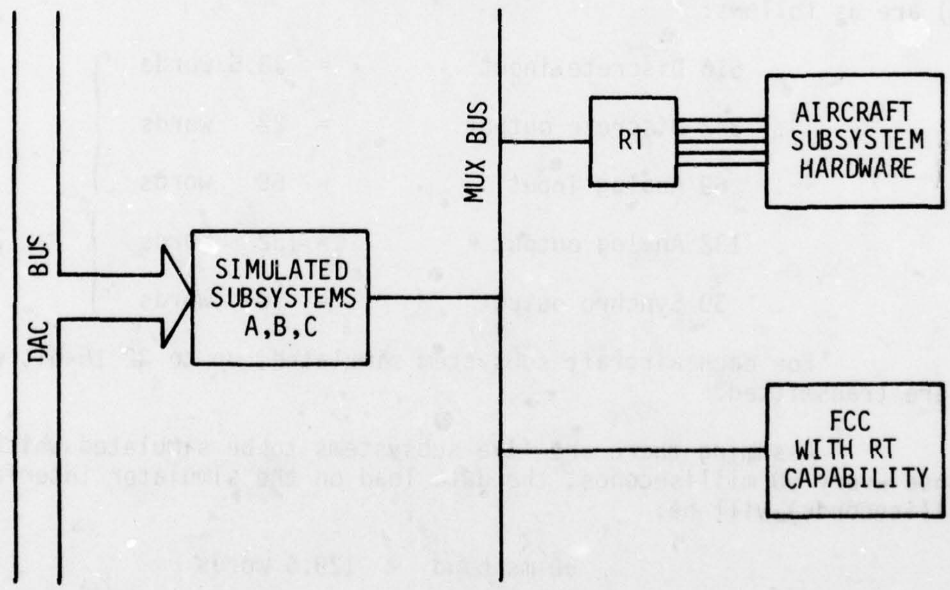



Figure 8-6. Alternative B for Multiplex Interface

The second solution would be cost effective only if the purchase of multiplex RTs overrides the cost of developing such an interface. This solution would also involve the greater risk in appearing as a multi-addressed device to the multiplex data bus controller.

The simulator interface is not interrupt driven. This creates the need for the interface to handle all protocol with the multiplex data bus and buffering of messages received from or to be sent to the simulation computer.

At present there is insufficient data to determine the trade-offs which have to be considered in choosing interfacing method. Some questions that remain unanswered are the number of subsystems which are to be simulated, the cost of RT and airborne hardware, the message density to simulated subsystems, and the requirements to load and monitor FCC during repositioning. A schematic diagram showing the overall interface layout including the Datapart C and special interfaces is shown in Figure 8-7.

The data rate of the multiplex data bus of 1 megabit/second can be met by the simulator interface.

The updating of the special purpose interface for airborne subsystems will be scheduled according to the subsystem's need. They will be scanned regularly as there is no interrupt capability.

The estimated requirements for the AH-64 simulator (in 16-bit words) are as follows:

| | | | |
|---|---|---|---|
| . 616 Discrete input | = | 38.5 words | 50 ms band |
| . 352 Discrete output | = | 22 words | |
| . 69 Analog input | = | 69 words | |
| . 132 Analog output | = | 132 words | 100 ms band |
| . 30 Synchro output | = | 30 words | |

For each aircraft subsystem simulated, up to 32 16-bit words of data are transmitted.

Assuming there are five subsystems to be simulated which need response every 50 milliseconds, the data load on the simulator interface (per 50 milliseconds) will be:

| | | |
|---|---|---|
| 50 ms band | = | 129.5 words |
| (100 ms band)/2 | = | 81 words |
| 5 special purpose inter. | = | 160 words |
| | | 370.5 words |

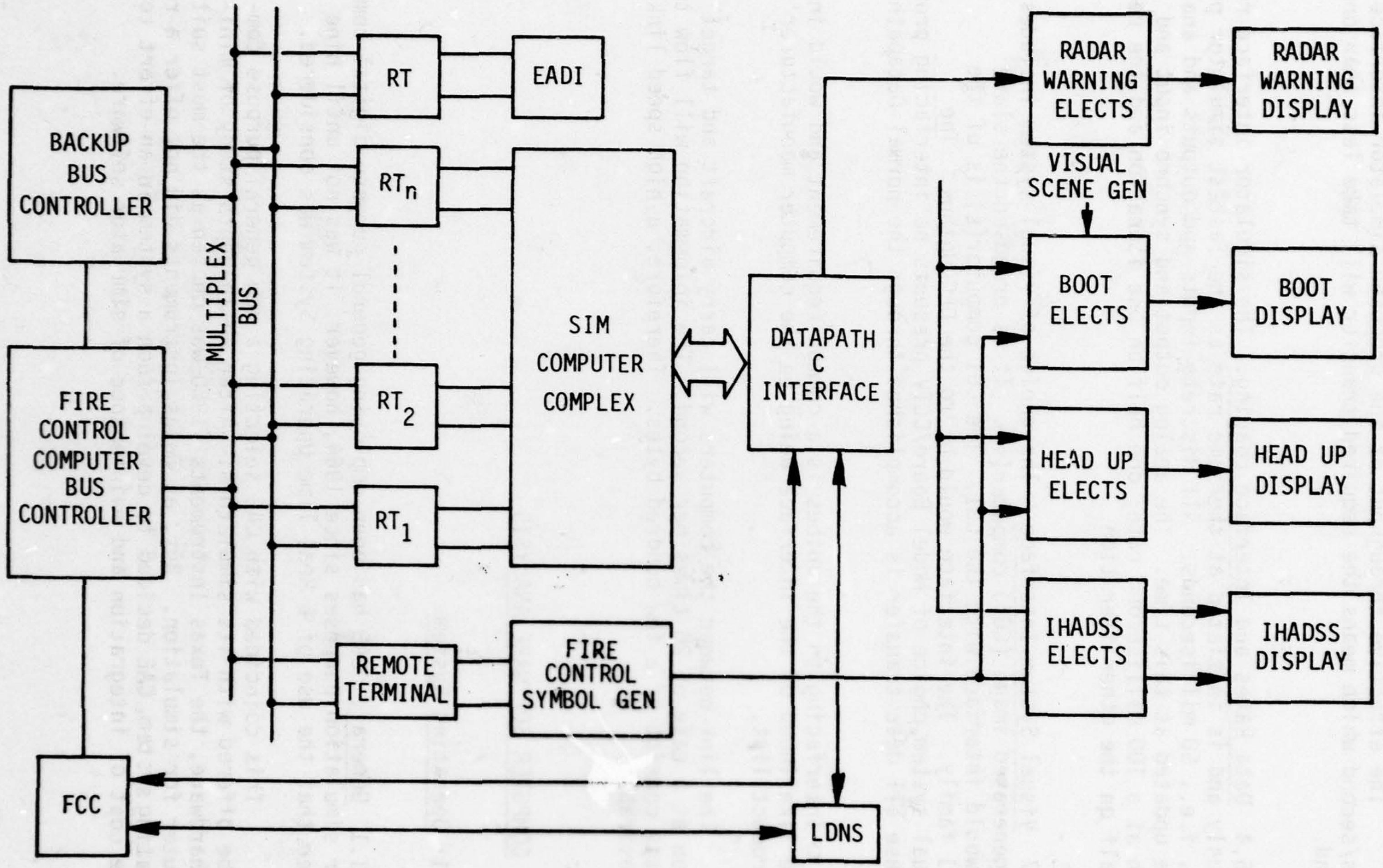



Figure 8-7. AH-64 FWS Trainee Module Interface Block Diagram

The effective throughput of the proposed simulator interface is 400K words/second which means the required transfer will take less than one millisecond.

8.3.6.4 Data Rates and Interface Loading. The simulator interface runs synchronously and is initiated at the same rate as the fastest simulator program band, i.e., 50 milliseconds. All discrete inputs and outputs and analog inputs are updated at this time. The analog output and synchro input and output run at a 100 millisecond rate; one half on one iteration and the remaining half on the other iteration.

8.3.7 Visual System Interface. The choice of visual system includes computer generated image (CGI) computer(s). It is proposed the slave computer would interface with the CGI. The CGI computer(s) is of the DEC PDP-11 family. The interface would be to the DEC Unibus. The other visual system choice of Model Board/CCTV presents no interfacing problems because all data transfer is accomplished through the normal Datapath C interface.

Interfacing to the unibus is a common requirement and would increase the likelihood of the interface being on the computer manufacturer's special product list.

The link between the computers will carry aircraft and target information at a rate of 20 times per second. The information will flow two ways and may consist of a few hundred bytes. Therefore, a high speed link will be desirable.

## 8.4 COMPUTER SOFTWARE ANALYSIS

### 8.4.1 Operating System

8.4.1.1 General. CAE has been employing general purpose digital computers for simulation purposes since 1964, however, it was not until nine years later that the use of a Real Time Operating System was considered.

This coincided with CAE selecting a new general purpose computer to be offered with its simulators. After an in-depth study of minicomputer hardware, the Texas Instruments TI980 was chosen as the most suitable computer for simulation. But, as Texas Instruments did not offer a real time operating system, CAE decided to develop such a system in an effort to reduce the cost of integration and maintenance of simulator software.

Until very recently CAE's simulator software was loaded into absolute memory locations; programs communicated with each other via a common or cross-reference area; access to data on mass storage was done using absolute addresses and to a certain extent each simulator system was self scheduling. All program maintenance was done off-line and on-line testing tools were minimal. Consequently, serious restrictions were imposed on the engineer implementing a program.

Each simulator system (i.e., flight, engines, ancillaries, etc.) had built in to it a buffer area to allow for patches and expansion. When this area was exceeded, all programs had to be relinked in order to create a new load module. This was a slow procedure and subject to multiple errors. It required the reading of all object tapes, which needless to say was an unpopular chore. In order to avoid this task it was customary to make patches 'permanent' by relying on a manual logging procedure for documenting them, creating an unreliable documentation procedure.

The scheme of using a common or cross-reference data area, to which all programs have access, has survived. It is essentially a good system in spite of some disadvantages. Traditionally, any change or rearrangement within a data base in the cross-reference area necessitated the reassembly of all programs that referenced the data base, as these references were resolved at assembly time. Some newer schemes, however, will resolve these references during the linkage of the program.

The use of fixed addresses in the mass storage device forced the user to be aware of the data location being accessed and needed to be advised of all changes concerning its location. Fortunately, this type of change was infrequent.

Having each simulator system handle the scheduling of its subsystems makes it difficult to implement a scheme whereby execution time is allocated to programs on the basis of their priority. A priority system would be desirable to execute the critical tasks first, or to activate tasks resulting from an event external to the task itself.

Some of the benefits expected from the development and use of a real time operating system were:

- Software configuration management
- Elimination of patches
- On-line program maintenance
- File management and disc resident load modules
- Better control of execution time and resource allocation

The result of this development effort was SIMTOS (Simulator Iterating Multi Tasking Operating System) at an estimated cost of 15 man years.

The opportunity of designing a real time operating system for simulation resulted in the inclusion of various features not normally found in 'off-the-shelf' operating systems.

These features were not part of the executive software but were utilities that play an important role during program integration and maintenance. They make it highly convenient for modifications to be made and bugs to be discovered and corrected. An estimated 20% of the total effort went into this area.

The remaining 80% went into producing the basic operating system, containing such modules as the scheduler, device drivers, interrupt processors, file management logic, as well as background utilities for editing, linking, etc.

Principal features of SIMTOS are as follows:

(a) Configuration Management is obtained as a result of a foreground configuration control utility which builds simulator load modules by consulting a list of the programs to be included. Programs can be added or deleted from this list. When the desired program configuration is obtained a load module is created by linking the programs on the list. This list also contains the revision number of each program and the date when it was added. A hard copy of this list is available at all times through the system console.

(b) Absolute patches were partially eliminated by making it easy to modify programs at a source level and to do so on-line. Programs can be relocatable and the engineer does not need to know where his program resides. Debugging aids allow the engineer to refer to his program location as positions relative to the start of the program. Hence, a one to one relationship with his program listing.

(c) The on-line program modification facilities allow a program to be edited, assembled and linked into the foreground load module. The new revision of the program would then be included the next time the simulator is loaded. The previous version of the foreground load module can be saved as backup. If the load module is not saved it is a simple matter to delete the faulty program and to replace it with a previous one.

(d) The implementation of file management means that files in mass storage (disc) can be referenced using a logical unit number which has been assigned to a file on the disc. Data can be retrieved from the file by referring to logical records. Records may be accessed either in a sequential or a direct fashion.

(e) Having load modules on disc allows various revisions of the foreground, diagnostics, background utilities, etc. to be readily available for loading and execution.

(f) Allocation of execution time and system resources to tasks is made on a priority basis by the resident portion of the operating system. A unique priority is assigned to each task based on the task's need for response from the operating system.

SIMTOS was later adapted to support a multi computer system. The computers were configured with a master-slave relationship. A slave computer is loaded with a subset of the operating system and acts as an extension of the master computer.

Real time operating systems offered by computer manufacturers do not differ widely from each other. They all include a basic operating system similar to that developed for SIMTOS, and the utilities necessary to create load modules to run under the operating system.

The memory requirements of vendor supplied operating systems with assembly capabilities are: 48K to 64K bytes for the nucleus and approximately 30K bytes for background. The same requirements in SIMTOS are: 24K bytes for the nucleus and 13K bytes for background; a saving of up to 47K bytes. This would represent 18% of a 256K byte memory configuration.

The cost of purchasing a real time operating system from a computer manufacturer can be as much as $5,000. This would include the assembler, source editor, etc. There would be an added cost for a larger memory configuration. For instance, 48K bytes may cost an additional $9,000 bringing the basic off-the-shelf operating system to $14,000 which is approximately 3% of the in-house development cost.

It is reasonable to expect that some enhancements and additions would have to be made to the basic operating system bought off-the-shelf. The enhancements would be in the area of on-line configuration control and integration aids. The additions would include device handlers for nonstandard devices and a mini executive for the slave computer(s). Assuming the cost of the enhancements would be the same as for the in-house system (20% of total) and the same effort again is needed for the additions to the operating system, a nonrecurring cost of six man years should be applied to the cost of the basic operating system.

Thus, the cost of modifying a computer manufacturer's supplied real time operating system to be used in a simulator is expected to be about 45% of the cost of developing an in-house operating system. This includes the cost of additional memory in one slave computer.

The recurring cost on subsequent systems would be the cost of additional memory and royalties for the vendor's operating system.

8.4.1.2 Operating System Requirements. The definition of an operating system should be broadened to encompass all the minimum software and utilities required to produce and execute any application program. An operating system by such a definition is expected to include:

- Operating system nucleus
- Loaders
- Source editor
- Assembler
- Linkage editor
- Debugging aids

8.4.1.2.1 Operating System Nucleus. The nucleus of the operating system is memory resident logic which for the most part executes in a privileged mode. It is usually made up of the following component subsystems:

- Operator communication program
- Scheduler
- Interrupt processors
- Executive call processors
- I/O subsystem programs
- File manager
- Resident loader

If one or more remote slave computers are part of the hardware configuration, a subset of the master computer's nucleus will need to reside in each slave. This subset would include the scheduler, interrupt processors, executive call processor and input/output subsystem programs. The removal of operator communication and file management could mean a potential saving of 32K bytes of memory for each slave over that of the master.

(a) The operator communication program handles all interaction between system and console device. It accepts commands from the console, decodes them and calls the required executor. It also provides the operator with system and user error messages.

The operator is able to interrupt a console function in order to enter a command.

(b) The scheduler supervises the execution of all tasks and system program operating on priority levels. Schemes for scheduling of execution time are available on a task priority basis or by time sharing.

When tasks are scheduled on a priority basis, the scheduler allocates execution time to the highest priority task ready for execution. Tasks priorities are defined when the tasks are created. Each task normally executes until it voluntarily relinquishes control to a lower priority task or loses control to a higher priority task requiring execution time. The time sharing method allocates each task a limited length of time, after which it interrupts if the task has not already relinquished control. Control is then given to another task in a round robin fashion.

Tasks relinquish execution time in one of the following ways:

- It places itself in an I/O or timer wait.
- It terminates itself.
- A higher priority task requires execution due to the occurrence of an external event.

The preferred scheduling algorithm is one where both the priority and time sharing methods are used. Since more than one task can have the same priority, time sharing can be done among tasks within the same priority level.

The scheduler also allocates memory space, as in the case of overlays or rolling out of lower priority tasks.

(c) The interrupt processor entry points are contained in dedicated trap locations. The computer hardware responds to an interrupt by saving the current status register and program counter, then branching to the location contained in the trap location.

The interrupts may be considered to be in one of two main groups. The first group, related to basic computer and software integrity, includes the following:

. Power fail/restart

. Illegal instruction

. Memory parity

. Arithmetic fault

. Memory access fault

. Privileged instruction violation

These interrupts are the highest priority and all but power fail/restore and illegal instruction may be disabled.

The second main group are interrupts originating from the various input/output devices and system clocks. Each device interrupts when it requires attention from the operating system. When the interrupt occurs control is passed on to the interrupt portion of the device handler.

Other interrupt types are such as one generated for executive calls.

Upon being activated, an interrupt processor normally saves the register contents, unless the computer architecture provides multiple register sets. When the interrupt processor's function has been completed, before returning to the preinterrupt state, the registers are restored.

It is desirable that the interrupts be assigned priority levels and that nesting of interrupts be possible. That is, higher levels of interrupts should be able to interrupt those on a lower level and then return to the lower level when finished.

(d) The executive calls also known as SVCs or monitor calls, are a group of pseudo instructions which allow tasks, running under operating system control, access to executive functions.

The executive functions offered by each of the various real time operating system differ in number and nature. The following basic functions should be provided:

. Input/output requests

Initiate and end task execution

. Synchronize task execution with real time clock

. Access to task status, memory limits, etc.

. Request time and date

. Load and execute overlays

. Device and file enquiry

. Allocation/deallocation of devices and files

Provision should be made for the addition of user defined executive calls.

(e) The input/output subsystem consists of the handlers for the various devices driven by the system. The executive call processor for input/output requests identifies the device requested by the task and transfer control to the handler.

The task will refer to the device or file through the use of a logical unit (LU) number which has previously been allocated to the task. The use of an LU number, allows the user to be independent of device or file name during the creation of his program. The device or file can either be defined at load time or dynamically by the task.

The device handler suspends the calling task until the input/output request has been satisfied. If the device is busy then the request is queued.

During the servicing of the input/output request the device may issue various interrupts to the system requesting service. These interrupts are directed to the interrupt servicing routine of the appropriate device handler. When an interrupt is received indicating the completion of the I/O transfer, the device handler will invoke the scheduler in order to return to the calling task.

All errors encountered by the device handler must be recorded.

(f) File management allows user tasks access to files on disc. A file is a collection of related logical records. These records are of an arbitrary length and structure which is unrelated to the size of the physical data block. The two forms of access to a file that will be provided are sequential and random.

The sequential access is the simplest form. The user performs a series of read/write requests to consecutive records on the file. The record pointer is automatically adjusted to point to the next sequential record unless a request is made to move the pointer, i.e., rewind, advance or backspace.

Random access requires the user to specify the record number that is to be accessed.

Direct access should also be allowed for transfers which need to avoid the file management overhead. File management, however, should ensure that the direct access does not conflict with other requests to disc.

(g) The resident loader processes programs in load module format from disc file. The load modules are created and placed on disc by the linkage loader. A load module may be a task or an overlay. The loader will perform any necessary biasing of relocatable data.

8.4.1.2.2 Loaders. The loaders are a family of software routines that read executable programs into memory. They may be either stand alone or be supported by the operating system.

The stand alone loaders contain their own device handling routines. The minimum requirement for stand alone loading is a system loader. This loader reads a memory image created by the linkage editor into memory from a specific file or device. This type of loader will initial program load (IPL) the operating system into memory.

The loaders supported by the operating system are scheduled by OS and issue executive calls to access the files to be loaded. The loader requirements for a real time operating system are the absolute loader and the resident loader.

(a) The absolute loader provides for rapid calling in of overlays or rolled out tasks. The programs are in a strict memory image format in order to avoid the extra overhead associated with loading relocatable programs.

(b) The resident loader is a general purpose routine which processes load modules produced by the linkage editor. All tasks and batch programs are loaded by the resident loader.

Modification is necessary to all loaders in order to cater to a multicomputer configuration.

8.4.1.2.3 Text Editor. The text editor is a background utility program that allows the creation and modification of assembler or FORTRAN source programs. Files can be operated on either interactively from a keyboard device or from a batch command stream. The minimum operations necessary are:

. Insert line(s)

. Replace line(s)

. Delete line(s)

. List line(s)

. End

These basic commands operate on the line or range of lines specified. In order to make the editing utility more useful the following operations should be included in the command repertoire:

. Set TABs

. Change character string

. Find character string and print

. Copy lines into another area of file

. Get source from another device or file

. Append to line

These commands save a lot of unnecessary repetition for the keyboard operator. By setting the TABs, the text editor can be used to edit source documents of any format and to avoid the needless typing of interfield spaces. The commands which operate on character strings eliminate the need to seek and replace multiple lines in order to change the same few characters in each line. The COPY and GET instructions allow repositioning of whole subroutines. By appending data to the present end of a line, the retyping of the line can be avoided.

The output of the text editor must be acceptable to the assembler or the FORTRAN compiler.

8.4.1.2.4 <u>Assembler.</u> The assembler reads the symbolic statements of a source file in order to produce a relocatable object program and a program listing. The assembler reads the source file statement by statement, translating a table of all symbolic references which cannot be resolved at assembly time. The relocatable object program will contain the executable code, program data and symbol table.

The program listing contains the source statements along with binary code generated for each instruction. A summary listing of the symbol table is also available.

Any errors encountered by the assembler are printed on the listing, identifying the nature of the error and the line in question.

The assembler also provides various directives which do not produce executable code. They fall into the following categories:

. Symbol definition: entry points, external symbols and equate symbol.

. Data definition: constants, reserve data blocks.

. Data structure definition: common block.

. Listing control: program name, page eject, title, etc.

. Location counter control: origin, absolute program, relocatable program, alignment.

. Assembler control: end assembly, conditional assembly.

The object code produced by the assembler can be processed by the linkage editor.

8.4.1.2.5 Linkage Editor. The linkage editor is used to combine relocatable object programs into a memory image load module in which all external common data area references have been resolved. The linkage editor is also capable of creating load modules for real time tasks, batch programs and overlays.

The commands to the linkage editor specify the object modules which are to be included, load addresses, overlays, priority, etc. A map of the load module should be produced defining the starting address, ending address, entry points and priority.

Load modules produced by the linking loader can be loaded by the resident loader and system loader.

The standard linkage editors may not be adequate in a simulator environment. This utility is likely to be modified or rewritten in order to take into account multicomputer configuration with common memory, to facilitate the on-line replacement of programs in the load module and to strengthen automatic configuration control.

8.4.1.2.6 Program Debugging Aids. To facilitate the check out of application programs, a debug program is included as part of the operating system. This debug program will allow programs to be tested in a background mode. The most common debug commands are:

- Dump memory location(s) or register(s)
- Modify memory location(s) or register(s)
- Snapshot dumps
- Modify program counter
- Breakpoint
- Trace

In order to make the debug utility useful in real time program integration, it is desirable to allow the debug utility to manipulate data and programs in master, slave and shared memories. The on-line debugging of simulator programs, however, must be done with no detectable disruption of the simulation process.

8.4.1.2.7 System Builder. The system builder allows the operating system to be modified or reconfigured. It may be defined as a separate utility or as a procedure using the linkage editor.

8.4.2 Programming Language

8.4.2.1 High Level Programming Languages. Programming in a higher level language undoubtedly means these programs are less time and memory efficient than those programs generated by assembler level language. The use of assembler level language was at one time justified by the relatively high cost of memory and the low throughput of the early generations of computers. New advances in the field of computer technology have altered the balance of hardware versus software cost considerably and have made newer computers faster than their predecessors.

Software produced by the manufacturer is responsible for the high cost of installing a system using assembler language. Often, before the software can be written, the programming staff has to be trained in an assembler language that is unique to the architecture of the particular machine. The knowledge of one assembler language cannot be directly applied to another vendor's machine. Programming in assembler language is time consuming and open to errors. Debugging at the instruction level is slow and difficult, even with sufficient debug tools. A long period of time is needed for the software to be ready. This is caused by various rewrites, major changes and optimizations necessary to execute within the original memory estimates. This could lead to a group of programmers different from those who designed the system taking over the program without adequate documentation. Often a program is rewritten in order to avoid piecing together a program that is peppered with patches.

In spite of all its faults, assembler level language is the most efficient way to use the machine's instruction set. Although it requires a good knowledge of the computer, it allows the programmer to take advantage of its good features while permitting him to avoid its poor ones.

High level languages, on the other hand, provide ease in programming and debugging. In some cases, the language is defined by strict industry standards in order to make them portable. That is, a program can execute on any computer that supports the language. High level languages are normally written in a highly readable notation and because of this they are self-documenting to a certain extent. Since all changes to a program are done at the source statement level, they remain up to date, making it relatively simple for others to understand or modify the program.

Each high level language has been developed to fill a general need in a particular area of the industry, i.e., COBOL in the business world and FORTRAN as an engineering/scientific problem solving tool. High level languages have a tendency to become inefficient in a highly specialized application because these languages cover a relatively broad field.

High level language compilers generate assembler level code or loadable object code. They do so by generating canned instruction or branches to subroutines. These are meant to deal with a wide range of possibilities and cause the compiler to generate more coding than is necessary making it convenient but inefficient in both execution time and memory usage. High level languages are not well suited to execute in real time. Some optimized versions have been released in order to make the resultant code more efficient in a real time environment.

8.4.2.2 <u>FORTRAN IV</u>. The high level language most widely used today for real time application is a superset of FORTRAN IV. FORTRAN is an acronym for FORmula TRANslation. It is a universal problem oriented programming language designed to simplify the preparation and checkout of programs.

The syntactical rules for using the language require that the user fully define the characteristics of his problem in a series of precise statements. These statements, known as the source program are translated by the FORTRAN compiler either directly into an object program or in some cases into a string of assembler level instructions as an intermediate step. In addition, when the compiler detects errors in the source statements, appropriate error messages are produced.

8.4.2.3 <u>FORTRAN IV Enhancements</u>. Early releases of FORTRAN were inadequate for real time purposes. As a result many of the computer manufacturers have made extensions to the basic FORTRAN IV as defined by ANSI standard X.3.9 - 1966.

The enhancements to FORTRAN IV will vary from one vendor to another. However, the most common enhancements are:

. Block optimization

. Real time extension

. ISA language extension

. Mixed mode option

. I/O extension

. In-line machine coding

8.4.2.3.1 Block Optimization. Optimization of separable blocks of source program can result in the reduction of both memory requirements and execution time. Common optimization block delimiters are: statement labels, start of DO loops, explicit calls to external subroutines and in-line coding.

Optimization can eliminate the need to reevaluate subscripts, this is particularly useful in DO loops. Elimination of needless calculation of known results is done by recognizing the reappearance of identical expressions. Careful management of the general purpose registers may avoid the unnecessary storing and retreival of temporary results.

Moreover, some forms of optimization which do not carry over more than one statement are done throughout the program. For example, whenever possible the compiler will make efficient use of immediate instructions, use register to register operations, avoiding the duplication of constants and generating in-line code for simple functions.

8.4.2.3.2 Real Time Extensions. The real time extensions to FORTRAN IV, although not a language feature in itself, permits the programmer to take advantage of available real time operating system features. These features allow a FORTRAN produced program to execute in a multitasking environment. Some of these features allow a task:

- Interaction with external events
- To obtain execution time
- File manipulation
- Fault detection and processing
- Inter-task communication and control
- Loading of overlays

8.4.2.3.3 Instrument Society of America (ISA) Language Extension. The ISA/Purdue workshop standards in addition to defining some of the real time features, recommended further language enhancements for process control. These features which permit processing of analog, discrete, and character string I/O include the following:

- Logical operations on bits and bit strings
- Logical shifting of bits
- Byte processing

8.4.2.3.4 Mixed Mode Options. The mixed mode option allows for expressions using items in a mixed arithmetic mode or logical mode. A mixture of arithmetical and logical items, however, is disallowed.

8.4.2.3.5 I/O Extension. Recent FORTRAN IV releases include READ and WRITE which allow run time interpretation of FORMAT statements. The FORMAT statement provides interpretation and editing of data between internal representation and external character strings. The ENCODE/DECODE facility provides memory to memory data manipulation and conversion between binary and ASCII.

8.4.2.3.6 In-Line Machine Code. The user may insert his own assembler level coding into the FORTRAN source file in order to have it compiled along with his FORTRAN statements. This useful feature enables the programmer to further optimize time critical routines or to strengthen areas in which FORTRAN is weak.

Compilers which optionally list the in-line code generated by each FORTRAN statement make the in-line machine code feature easy to use.

8.4.2.4 Summary and Conclusion. The major forces behind the migration to a higher level language such as FORTRAN IV are:

- The degree of machine independence they provide
- High readability
- Reduction of software production cost

FORTRAN is transportable but will normally require some modification before it can run on another machine. Manufacturers have a tendency to include in their compiler subroutines which are in addition to references to these subroutines as defined by ANSI. All in-line codes must be rewritten when changing machines.

The inherent readability of FORTRAN improves the uniformity of coding and makes logic more visible.

The reduction of software production cost is a direct result of the machine independence and its high readability. It avoids expensive training of a new language and eliminates the need for the programmers to learn the precise details of a new computer architecture, and because of its readability it decreases the cost of program maintenance.

It is generally assumed that the compiler will produce near optimum code for that machine.

Optimization, however, largely depends upon the programmer's knowledge of the optimization techniques of the compiler and his ability to keep the optimization blocks as large as possible.

Since a high level language compiler will not always make the most efficient use of the machine's instruction set, it will often be necessary to drop into assembler level coding. Using in-line assembler code can potentially destroy the higher level structure of the language by corrupting register content or making illegal entries into subroutines. It will also defeat the self-documenting features of the language unless adequate comments are inserted.

FORTRAN displays weaknesses in performing functions which are essential in a simulator application. These areas are:

- Manipulation of bit strings
- Bit testing and modification
- Byte manipulation

Boolean operation and shifting of bit strings is required in the manipulation of discrete inputs and outputs. Decisions are often made based on the binary state of an *individual bit* (Yes/No, On/Off, etc). The ability to look at and modify bytes (ASCII characters) is extremely useful in interacting with the instructor station.

Precise figures on the benefits of the use of FORTRAN IV as compared to the use of assembler are vague and difficult to come by. To quote one source:

> "Economics obtained from High Level Languages in application programs reduce the needed manpower by 45% even though it increases core requirements by 20% and execution time by up to 45%."" (Ref.8-1)

It is evident, however, that the use of high level languages has its drawbacks. With the advent of inexpensive high performance computers, the price of using high level languages such as FORTRAN may be tolerated particularly since it can be made more time and memory efficient through the use of in-line assembler code.

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Ref.8-1. Introduction to the Real Time Operating System, Data General Corporation, 093-000093, Rev. 02, March 1975.

The ultimate test for any language is in its performance in a practical application and it is only here that a correct mixture of FORTRAN and assembler code can be determined.

FORTRAN IV was not explicitly intended as a simulation language. But if the need for a simulation language persists, FORTRAN IV could become the basis for a new high level simulation language. A total commitment to FORTRAN, however, is not without its risks as it could be replaced by a language which has been designed for simulation. An example of such a language is CORAL 66, now widely used in the United Kingdom.

8.4.3 Simulation Software. The details of simulation software necessary for this study are discussed in other sections of this document and are only referred to here.

Program Memory Size and Execution Time Estimates for AH-64 Simulation Software in assembly language are contained in Table 8-11.

The bases of simulation in software design is referred to in the following sections/paragraphs:

| | |
|---|---|
| Power Plant | paragraph 3.7.2 |
| Ancillary Systems | paragraph 3.7.3 |
| Flight Systems | paragraph 3.5 |
| Motion System | Section 6 |
| Radio Aids | paragraph 3.6 |
| Visual | Section 5 |
| Weapons | Section 4 |

8.4.4 Diagnostics. The use of diagnostic programs in a simulator or any computer configuration serves to verify the correctness of operation of each hardware module. A diagnostic program could execute either on-line or off-line. On-line diagnostics execute alongside the other system functions. In a real time system, the on-line diagnostics can either be a core resident task which is scheduled at regular but low priority basis, or they can be loaded and initiated on demand from the operator console.

The function of on-line diagnostics is to perform limited exercising of CPU functions and I/O channels, checking device status, and recording the occurrence of recoverable errors. On-line diagnostics will rarely be supplied by the computer manufacturer.

Off-line diagnostics will be supplied by the computer manufacturer for their CPU and all standard peripherals. They require that the computer and whatever I/O module is being tested is dedicated to the diagnostic. As they execute during 'down time', they are used for preventive maintenance or to isolate an existing fault down to the lowest possible level. Since they are not required to share the system's resources, they perform a more rigorous test of the hardware than can be done by on-line diagnostics.

The dynamic exercising of hardware modules by on-line diagnostics ties up system resources for varying periods of time. The amount of time required by each test or exercise would depend upon the degree to which the test is to be made. The more thorough the test is to be the longer the period of uninterrupted time it will require, and the greater the risk of reducing the quality of simulation. When simulation is the prime function of a computer system it would be unacceptable to compromise this function in any way.

In a simulator configuration, where little or no redundancy exists, the failure of a simulator critical component would mean the unavailability of the full system. The early detection of failures by an in depth on-line diagnostic program would not serve to avoid the system failure but would only indicate the mission must be stopped and the part replaced. In view of this, the value of devoting a great amount of time to the development of comprehensive on-line diagnostics is questionable, since they will not appreciably reduce the amount of down time. Their function is also difficult to define by anyone unfamiliar with the details of the hardware.

A more effective way of detecting errors is to schedule regular preventive maintenance sessions during which off-line diagnostics, as supplied by the computer vendor, are executed. During the simulation process; on-line diagnostics will be limited to performing regular checks of the system integrity, record the occurrence of recoverable errors and abort the system when a fatal error occurs. The diagnostic features presently available on the Datapath C Interface currently under production at CAE are featured in Appendix F.

8.4.5 General Purpose Utilities. The general purpose utilities are a group of unrelated programs which facilitate the maintenance of the system software. Whatever their name or number they will fulfill at least the following functions:

. Initialize the disc volume(s)

. Disc file maintenance

. Provide backup for disc(s) to magnetic tape

. Allow restoration of disc files from magnetic tape

- Provide statistical information regarding execution time and disc usage

- Maintenance of subroutine libraries

- File verification

- Maintenance of data on fixed head disc

In many cases existing software will suit the simulator system's needs, in others the utility will have to be written or an existing utility altered.

8.4.6 Available Software. Both computer vendors considered for the AH-64 simulator configuration provide a comparable repertoire of software packages. Table 8-22 itemizes the available software from each supplier (as required by AH-64 simulator).

The Operating System (OS) chosen from either vendor is a real-time multi-tasking operating system. They differ slightly in design but essentially offer the same capabilities. There is no standard OS offered which supports a slave computer nor is there an OS intended to reside in the slave. Both of these are required by the AH-64 simulator.

The nature of the changes to the master CPU's operating system will vary with the choice of computer since the hardware interface will not be the same for both. Basically, the function of the modification is to synchronize the slave CPU with the master and provide for asynchronous messages in order to exchange data and status. The slave computer will contain a primitive version of the operating system. The slave operating system will contain the logic necessary to schedule and support executive calls for slave resident tasks.

In addition, the initial program loader (IPL) and resident loaders need to be modified or developed to support the slave computer.

Device drives for the simulator interface, graphic display, visual system interface and the hard copy unit will be developed and incorporated into the operating system.

Program development utilities, such as source editor, assembler, linkage editor and debug aid, are offered by both vendors.

TABLE 8-22. AVAILABLE SOFTWARE

| SOFTWARE ITEM | SOFTWARE AVAILABLE INTERDATA | SEL |
|---|---|---|
| Operating System | OS/32 - MT | Real Time Monitor (RTM) |
| Minimum Requirements | 7/32 or 8/32 CPU<br>128 KB memory<br>Operator Console Panel<br>Power fail/Auto restart<br>Memory Access Controller<br>Operator Console<br>Universal Clock<br>Mag. Tape or Disc | SEL 32 Processor<br>128 KB memory<br>Real Time Option Module<br>Operator Console<br>Card Reader<br>Printer<br>Disc Storage<br>Mag. Tape |
| Assembler | Common Assembler Language (CAL) | Macro Assembler |
| FORTRAN Compiler | FORTRAN VI | Extended FORTRAN IV |
| Source Editor | OS EDIT | TSS - Text Editor |
| Linkage editor | Task Establisher | Cataloger |
| Debug | AIDS/32 | TSS - Interactive Debug |
| Multi Terminal Exec | - | Terminal Support Subsystem (TSS) |
| Other Utilities | . Configuration Utility<br>. Disc Dump Utility<br>. Disc Initializer | . Datapool Editor<br>. Media Conversion Proc.<br>. File Manager<br>. Macro Library Editor<br>. System Editor |

SEL's source editor and debug program form part of a multi terminal package, terminal support subsystem (TSS). Although TSS is in itself a useful feature, the interactive debugging programs are not as powerful as Interdata's. It lacks a snapshot dump and trace features. All other essential commands are included. However, the debug utility from either vendor would need to be modified in order to allow snapshot dump of registers, memory dump and memory change, of real time programs in both the master and the slave computers.

Both FORTRAN compilers include enhancements to FORTRAN IV as defined by ANSI standards. These enhancements include:

- Block optimization
- Real time extension
- ISA language extension
- Mixed mode option
- I/O extension
- In-line machine coding

The relative merits of each compiler cannot be ascertained without performing comprehensive benchmarks on each computer. These benchmarks should be representative of a simulation problem and take into account operating system and I/O overhead. The same benchmarks should be wholly or partially written in assembler in order to evaluate FORTRAN as a high level simulation language.

One outstanding feature which is provided only by SEL is the concept of 'Datapool'. Datapool was developed by SEL explicitly for simulation in order to ease cross-reference building and maintenance. It is superior to the traditional common data area in that a user does not need to define each label referred to in the common area by relative location and size, but rather merely defines the labels as being in the common area or datapool. Modifications or rearrangements of the common area, traditionally require reassembly or recompilation of all programs that make reference to the changed position. With Datapool it is only necessary to relink (recatalog) the programs.

The general purpose utilities provided by the computer manufacturer would have to be supplemented by customized utilities which will:

- Provide statistical information regarding execution time and memory usage of each program or system
- Allow multiple files to be copies from disc to magnetic tape as backup

. Restoration of disc files from a multi file magnetic tape

. Maintenance of data bases on the store computer's fixed head disc

Special purpose utilities, which will be developed in house, include data base editors for radio aids, visual, CRT pages, etc.

## 8.5 COMPUTER MODULE SELECTION

In the course of the 32-bit minicomputer analysis, it has become increasingly evident that neither manufacturer, Interdata nor SEL offers a computer with any features to give one vendor a distinct advantage over the other.

The following three models of computers are considered adequate for the FWS:

. SEL 32/75 (600 nanosec. memory and HSFP)

. Interdata 8/32 (750 nanosec. memory and HSFP)

. SEL 32/55 (600 nsec memory, no HSFP)

Although only the SEL 32/75 meets the 100% spare time requirement, the other two models (Interdata 8/32 and SEL 32/55) cannot be disregarded, in spite of their slightly lower processing capacity, they are capable of meeting the FWS requirements at a reduced cost.

In the case of all computer models, a dual computer configuration is essential to provide good fidelity of simulation and adequate spare capacity. The use of a high speed floating point processor is not mandatory in SEL 32/75 configuration; it can be omitted initially and added later if the spare execution time in either CPU ebbs to a critical level. All recommended configurations have ample room for expansion both with regard to memory and I/O capability.

# SECTION 9

# INTEGRATED LOGISTIC SUPPORT

## 9.1 INTRODUCTION

In order to meet the Integrated Logistic Support (ILS) program requirements of the army for the AH-64 FWS, it will be necessary to implement a logistics support plan to generate and analyze the required logistics related data, and to ensure that the Logistic Support Analysis is interactive with the system development. This effort must commence with conceptual design and must continue throughout the full development and deployment of the system. The analytical work to be performed will require the compilation of data from many disciplines, which data must be current with design approaches. The analysis of these data must consider the impact of each element of the system, and its design approach, on the logistics aspects of the total program. The analysis must be timely, and the results of the analysis must be interactive with the design activity by influencing the design approach in a manner which enhances the operability and supportability of the system.

## 9.2 ORGANIZATION

We believe that fulfillment of all the elements of an ILS plan requires the appointment of an ILS Project Manager to head an organization shown in Figure 9-1. His function in the overall program is to interface with the Project Management Office and with Project Engineering in all decision making which in any way affects the Logistic Support Plan for the system. The ILS Project Manager's basis for such inputs into the decision making process must be the results of the analytical efforts of the ILS Project team, which reports directly to him.

The ILS Project team consists of coordinators whose responsibility will be to obtain relevant data from the various departments involved in design, manufacturing and support, analyze said data, and take necessary action, based on the analysis, to ensure achievement of the Logistics Support objectives. The coordinators interface directly with the operating departments responsible for the various disciplines, and, as a team, integrate the various logistics support related activities into a coordinated effective program.

The responsibility for adherence to the Logistics Support objectives of the program rests with the ILS Project Manager. The provision of the necessary data for the Logistics Support Analysis (LSA) rests with the operating departments (Systems Engineering, Equipment Engineering, Engineering Test, R & M, Provisioning, Training, Tech Pubs and Field Service).

A constant awareness of current Logistics Support posture and objectives must be maintained by direct liaison and interfacing between the logistics coordinators and the operating departments.

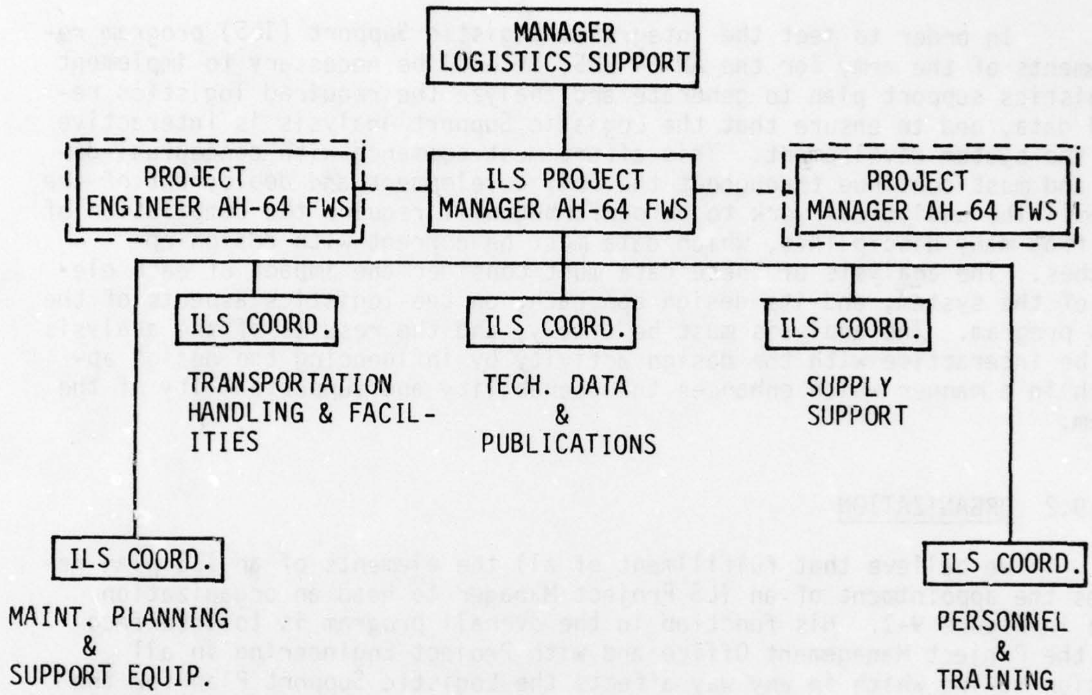


Figure 9-1. ILS Project Team

## 9.3 INTEGRATED LOGISTICS SUPPORT OBJECTIVES

The overall objective of an ILS effort is to enhance the effectivity of the product, in meeting the training mission requirements of performance, availability, operability and supportability through its life cycle, at reasonable cost. Attention to the significant elements affecting operation and support costs, in an integrated fashion, will produce a viable product, and a realistic support system for that product. The aforementioned objectives can be achieved by establishing guidelines to be adhered to during design and development of a trainer. Guidelines required to cover these stages of the AH-64 FWS are as follows:

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AH-64 FLIGHT AND WEAPONS SIMULATOR CONCEPT FORMULATION STUDY. V--ETC(U)
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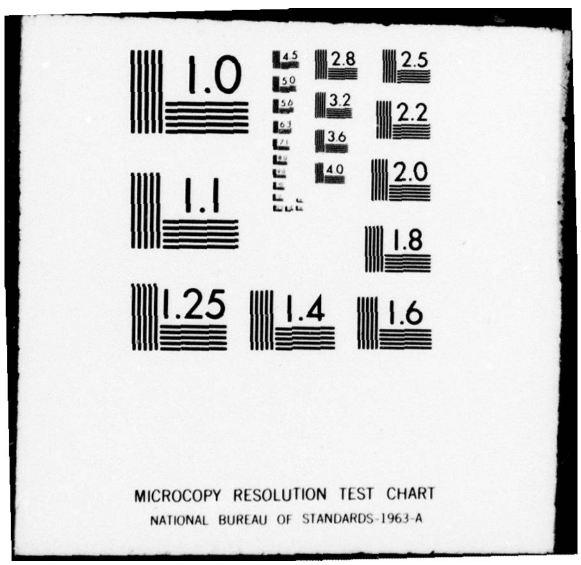

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

- The system must be designed to be as reliable as possible within the operating and cost constraints of the program.

- The system must be designed to minimize maintenance time by making best use of self test and diagnostic features. The objective in this is to assure maximum availability by reducing fault finding time. Additionally, repair time must be minimized by intelligent use of modular equipment where possible, permitting a rapid removal/replacement cycle.

- The system must be designed around standard parts, wherever possible and practicable, in order that the need for multiplicity of spare parts may be minimized. Similarly affected by the use of standard items is the necessity for special or unique support equipment. Equipment of this class is generally very costly, and the requirement for it should be minimized.

- By virtue of the complexity of the AH-64 simulator system, specialized skills will be required for its operation and maintenance. These skill requirements must be identified early in the program, and minimized where possible. The system should be designed for maintenance, on-site, down to the piece part of component level. This concept must apply wherever practicable in the system. Exceptions to this concept must be limited to system elements, which by their nature, may require specialized repair facilities, special support equipment, or special processing or repair environment, such as cannot be practically provided on-site. Utilization in the system of such items as described above must be limited to those applications where there is no practical alternative.

- Spare parts provisioning must consider the maintenance concept in the recommendation of spare and repair parts. Additionally, depot repair cycle time, reliability, maintainability, must be thoroughly analyzed in order that an effective and economic supply support program may be realized.

- Engineering data and technical publications must be of a quality, and to a level of detail consistent with the level of maintenance to be performed by the user. The use of existing documentation (vendor data) for off-the-shelf items should be given serious consideration where such data provides the required information in the most cost effective manner.

- Training of maintenance and operator personnel must accordingly be tailored to meet the user concept and philosophy of maintenance and operation, and the user's personnel skill classification.

## 9.4 CONCLUSION

The intent of an Integrated Logistics Support Program such as described above is to identify elements affecting operating and support costs and to use this information to optimize life cycle costs. It is recommended that the ILS analytical effort, particularly in the area of detail trade-off studies, be kept to a practical minimum where proven off-the-shelf hardware, which meets the support plan guidelines, is to be used.

The Logistics Support Analyses should be directed at the main cost incurring elements of the system during its intended life, namely: maintenance and spare parts. If these can be realistically reduced, and accurately projected, the largest portions of Operating and Support costs can be well controlled to the maximum degree.

# SECTION 10

# CONCLUSIONS

## 10.1 INTRODUCTION

Sections 3 through 8 of this report have discussed in detail various possible designs for the individual FSW trainer subsystems. Each section concluded by recommending a particular subsystem design or configuration which has been selected as the best response to training requirements, development costs, and reasonable production deadlines. This section is a summary of those conclusions and as such defines our recommended FWS design.

## 10.2 BASIC FLIGHT SIMULATOR DESIGN ANALYSIS (Section 3)

The construction of a trainer to teach basic IFR skills, instrument navigation, and cockpit procedures for normal and abnormal conditions of helicopter equipment, excluding Visionics, is within present engineering capabilities. Section 3 recommends detailed design approaches for the basic flight simulation system; most of these have already been successfully used by CAE in previous helicopter simulators.

Due to constraints imposed by the visual system, it will be necessary to provide separate cockpits for the pilot and copilot/gunner. Since the simulator cockpit shells will then differ from the actual aircraft shell, it is recommended that the simulator shells be fabricated by the simulator manufacturer. Since the cockpits are split, controls such as collective, cyclic, pedals, and throttles, which would be mechanically linked in the real aircraft, must be simulated, using programmable load units and positioning systems.

It is recommended that wherever possible actual aircraft instruments, control panels, and special AH-64 subsystems be used. This will ensure realistic training and is more cost-effective.

Modelling of aircraft flight is not expected to provide any major difficulties. However, the flight simulation can only be as good as the data package furnished by the aircraft manufacturer. Since this is a high-performance aircraft that can operate under a wide variety of conditions, a thorough set of flight data must be provided to ensure correct simulation at the limits of aircraft performance.

Realistic modelling for atmospheric wind and turbulence conditions in terrain flight is quite feasible for moderately contoured ground areas, but for highly detailed areas, such as towns, or small local perturbations, such as those around individual trees or clumps of trees, data is lacking on wind effects. Unless a study is undertaken to determine the actual wind patterns around these complex objects, it will not be possible to realistically simulate turbulence effects.

The communications and navigation systems are similar to present simulated systems. However, the Doppler Navigation System (DNS) simulation will require some development. The preferred method of simulation is to use

the aircraft Computer Display Unit (CDU) itself and generate its input signal under computer control.

### 10.3 WEAPON AND SIGHTING SYSTEMS (Section 4)

CAE believes that simulation of the trajectory and impact points of weapons is feasible in the AH-64 FWS. The approach recommended for the Fire Control Subsystem is to use AH-64 aircraft parts for the Fire Control Computer (FCC), IHADSS, TADS display, FCC symbol generator, and weapon control panels and to provide the simulation software for the TADS weapon subsystem control and Laser Rangefinder/Tracker.

The recommended design for the Radar Warning System is to use the aircraft display unit and generate the symbology and audio warnings from simulation hardware under program control.

### 10.4 VISUAL SYSTEM (Section 5)

At present, CAE believes that either of two alternative out-of-the-window visual scene generation systems could be used for the AH-64 FWS. These are the Model Board/Field-Sequential CCTV system and the Computer Generated Imagery system with texture.

The extra realism provided by the model-board approach, together with the fact that the restricted playing area does not seem to impose a severe restriction on missions in which 'shooting' is the prime training task, leads us to recommend the model board-approach.

The recommended visual display arrangement is a dome/projection system. A group of three projectors, moving under servo control to follow the pilot's head, projects a $110^{o}$ by $50^{o}$ scene on a 12-foot radius dome covering a $220^{o}$ by $70^{o}$ field of regard. This system provides a strong visual cue from a wide field of view while being substantially cheaper and lighter than a comparable pancake window display system.

The display system design requires the choice of a two-cockpit configuration for the simulator.

CAE recommends the use of computer generated imagery for the generation of TADS and PNVS visionic video because of the impracticability of adapting Model Board/CCTV techniques to FLIR simulation and to the high magnifications required by TADS. The use of AH-64 aircraft equipment is recommended for the IHADSS and TADS displays, with the exception of the Direct View Optics, which must interface with CRT displays.

### 10.5 MOTION CUEING SYSTEMS (Section 6)

It is concluded that motion cueing is an essential requirement for effective crew training in the AH-64 simulator.

The three basic elements of the recommended motion cueing system are a seat shaker, a g-seat, and a cockpit motion system. The seat shaker is required for both the pilot and copilot to simulate the effect of helicopter vibration and buffet. The seat shaker is capable of providing these cues without degrading the visual displays. The g-seat provides the pilot with the correct acceleration cues. It is probably not required by the CPG, since flying the helicopter is the least important of his training tasks. The cockpit motion system is required to generate a response to control inputs by the pilot and allow him to realistically fly the simulator under both VFR and IFR conditions. The copilot will also need a cockpit motion system to provide him with the conflicting and possibly nauseous motion cues while he is operating in the head-down target acquisition mode. Because of constraints imposed by the visual system, separate cabs and motion bases will be required.

Of the two proposed cockpit motion systems, the standard horizontally mounted six-degree of freedom design is preferred. This system is presently available in a military standard design, promising fast delivery at low cost. However, should greater pitch and roll cues be required, a side-mounted system could be developed. Higher development costs and a delayed production schedule would be the disadvantages of this design.

### 10.6 INSTRUCTOR/OPERATOR CONTROLS (Section 7)

A study of the instructor control requirements has led to a preliminary design for the FWS instructor's facility based on the following conclusions:

- The instructor requires automated features under his own control.
- The instructor should be able to monitor students directly if he desires.

In the light of these conclusions and certain visual display requirements, an FWS configuration of separate pilot and CPG training modules, each with its own instructor's station, is recommended. The instructor's location should be such that he can monitor student actions directly.

Each Instructor's station should be capable of monitoring and controlling either or both cockpits to permit crew training with only one I/OP (Instructor/Operator) if necessary.

It is our conclusion that a system providing CRT pages for information and control presents sufficient capability for instructor control. The Sanders Graphic 7 Display Generation System is the recommended hardware to use in driving four CRT's, two for each instructor. The inclusion of visual monitors reflecting TADS and PNVS video scenes is also recommended. A preliminary instructor's station design and a group of recommended instructor software utilities is shown in Section 7.

## 10.7 COMPUTER AND PERIPHERAL ANALYSIS (Section 8)

A twin CPU configuration employing 32-bit minicomputers is recommended for the FWS. Of the presently available machines, either the SEL or Interdata minicomputers could be used. Since a number of 32-bit minis are under development at present, CAE believes it is in the best interest of the program to delay computer selection as long as possible. A moving head disc, a tape drive, and a fixed head disc are among the recommended peripherals.

The DATAPATH C interface recently introduced by CAE will be capable of controlling the AH-64 FWS data transfer between trainer and computer. The presence of AH-64 aircraft equipment will require expansion of the interface to include special modules. Design is expected to be readily feasible on receipt of equipment interface data.

The adaption of a manufacturer's Operating System (OS) to the simulator needs is estimated to cost less than developing an OS in-house.

CAE feels that the use of a FORTRAN and assembly language mixture would provide a more efficient use of computation time than the use of FORTRAN alone. The nature of the mixture is dependent upon the selection of the computer.

CAE concludes that the use of on-line diagnostics is questionable since they will not appreciably reduce the amount of downtime. A more effective way of detecting errors is to schedule regular preventive maintenance sessions during which off-line diagnostics are executed. At the time of this report, we have reached no conclusions on the relative advantages of semiconductor memory versus core memory. Neither SEL nor Interdata currently supply semiconductor memory, but we intend to reevaluate the situation when it becomes available on these machines.

## 10.8 SUPPLEMENTARY TRAINING DEVICES

As pointed out in Section 2, the use of the full mission simulator for training all tasks is considered undesireable. While the full mission simulator must provide the capability for total and part-task training, it seems less cost-effective to use the mission simulator to conduct extensive part-task training programs. CAE feels that there are certain areas in which supplementary training devices would prove more cost-effective.

Some of these areas are:

(a) Transition Training. The trainer would not require motion or visual systems. Aircraft controls, instruments, and sound would be provided.

(b) TADS and Weapons Trainer. A trainer could be devoted purely to training use of the TADS visionics systems, including target detection through weapons release. Flight instruments and controls, sound, out-of-the-window visual display and motion would not be required. TADS video would be CGI.

(c) Navigation/Route Planning. Navigation can be trained with a program such as MAITAC. Route planning could be trained using a computerized route analysis system. The trainee could enter his projected course on a computerized map display system. The computer could calculate the area within which the helicopter could be seen by ground troops or vehicles. Various courses could be selected by the trainee to try to minimize his exposure.

(d) IHADSS Trainer. This could be integrated with the TADS trainer. It would provide the pilot or copilot practice in the use of the sighting systems, PNVS video and symbology, and the area weapons. The video and symbology would be provided by a CGI system.

The supplementary trainers should be simple to operate, allowing the pilot or copilot to control the training without the need of instructor intervention.

## 10.9 SUMMARY

To summarize, the recommended AH-64 FWS consists of the following:

- Two cockpits, each with instructor's station
- Two horizontally mounted 6-degree of freedom motion bases
- Two seat shakers, plus pilot g-seat
- Dual 32-bit minicomputers
- Two 24-foot diameter dome color projection displays, using Area of Interest (AOI) technique
- Two Model Board/Field Sequential CCTV Systems
- Dual-channel CGI system for TADS/PNVS/FLIR

. Standard flight/communications/navigation/motion programming

. Special tactics/line of sight/visual safety programs

. Standard aircraft parts and systems, used wherever feasible and economic

# SECTION 11

# RECOMMENDED AH-64 FWS CONFIGURATION

## 11.1 INTRODUCTION

This section describes the estimated costs involved in the procurement and operation of the AH-64 FWS configurations recommended by the study program. The cost estimates are preceded by a technical description of FWS components and performance, consideration of facilities required for operation, and the design and manufacturing standards involved in the production of a developmental model.

A cost effectiveness analysis comparing the estimated total cost of the FWS plus operating costs over 10 years against the estimated operating cost of the AH-64 is also included in this section.

In addition to the recommended FWS using a model board/CCTV visual system this section contains an analysis for an alternative configuration using a purely CGI visual system.

## 11.2 AH-64 FWS TECHNICAL DESCRIPTION

The recommended AH-64 FWS technical description has been constructed from the AH-64 concept formulation study conclusions detailed in Sections 2 to 10. The simulator complex envisaged for the FWS is illustrated in Figures 11-1 and 11-2 and recommended flight compartment and projection system layouts can be found in Figures 11-3 to 11-6.

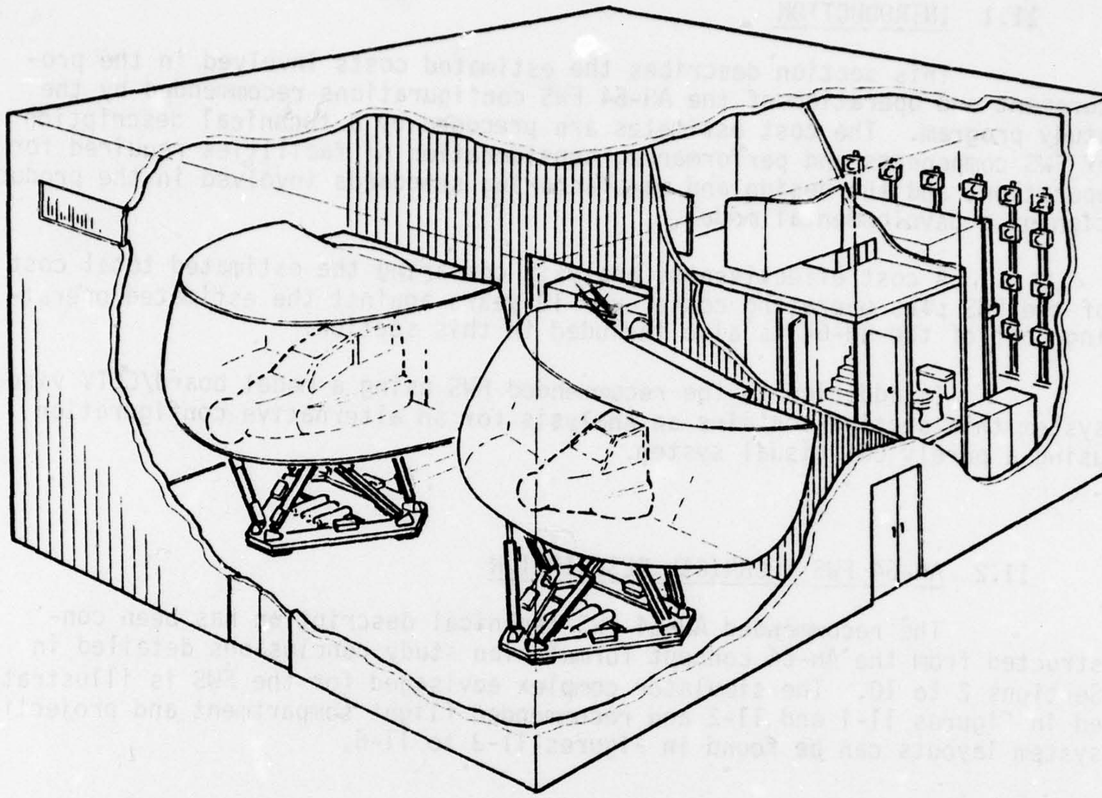
11.2.1 Components. The following features illustrate the major components of the recommended AH-64 FWS:

(a) Flight compartment

- Separate pilot and CPG trainee stations mounted on separate motion systems.
- Instructor stations mounted behind each trainee station.
- Air conditioning system to provide comfort cooling.

(b) Motion cueing systems

- 6-degree of freedom motion system for each flight compartment.
- Seat shaker unit for each trainee seat to introduce vibrations.
- Pilots G-seat to introduce prolonged acceleration cues.



- TWO COCKPITS, EACH WITH INSTRUCTOR'S STATION
- TWO HORIZONTALLY MOUNTED 6-DEGREE OF FREEDOM MOTION BASES
- TWO SEAT SHAKERS, PLUS PILOT G-SEAT
- DUAL 32-BIT MINICOMPUTERS
- TWO 24-FOOT DIAMETER DOME COLOR PROJECTION DISPLAYS, USING AREA OF INTEREST (AOI) TECHNIQUE
- TWO MODEL BOARD/FIELD SEQUENTIAL CCTV SYSTEMS
- DUAL-CHANNEL CGI SYSTEM FOR TADS/PNVS/FLIR
- STANDARD FLIGHT/COMMUNICATIONS/NAVIGATION/ MOTION PROGRAMMING
- SPECIAL TACTICS/LINE OF SIGHT/VISUAL SAFETY PROGRAMS
- STANDARD AIRCRAFT PARTS AND SYSTEMS, USED WHEREVER FEASIBLE AND ECONOMIC

Figure 11-1. Artist's Conception of Simulator Complex

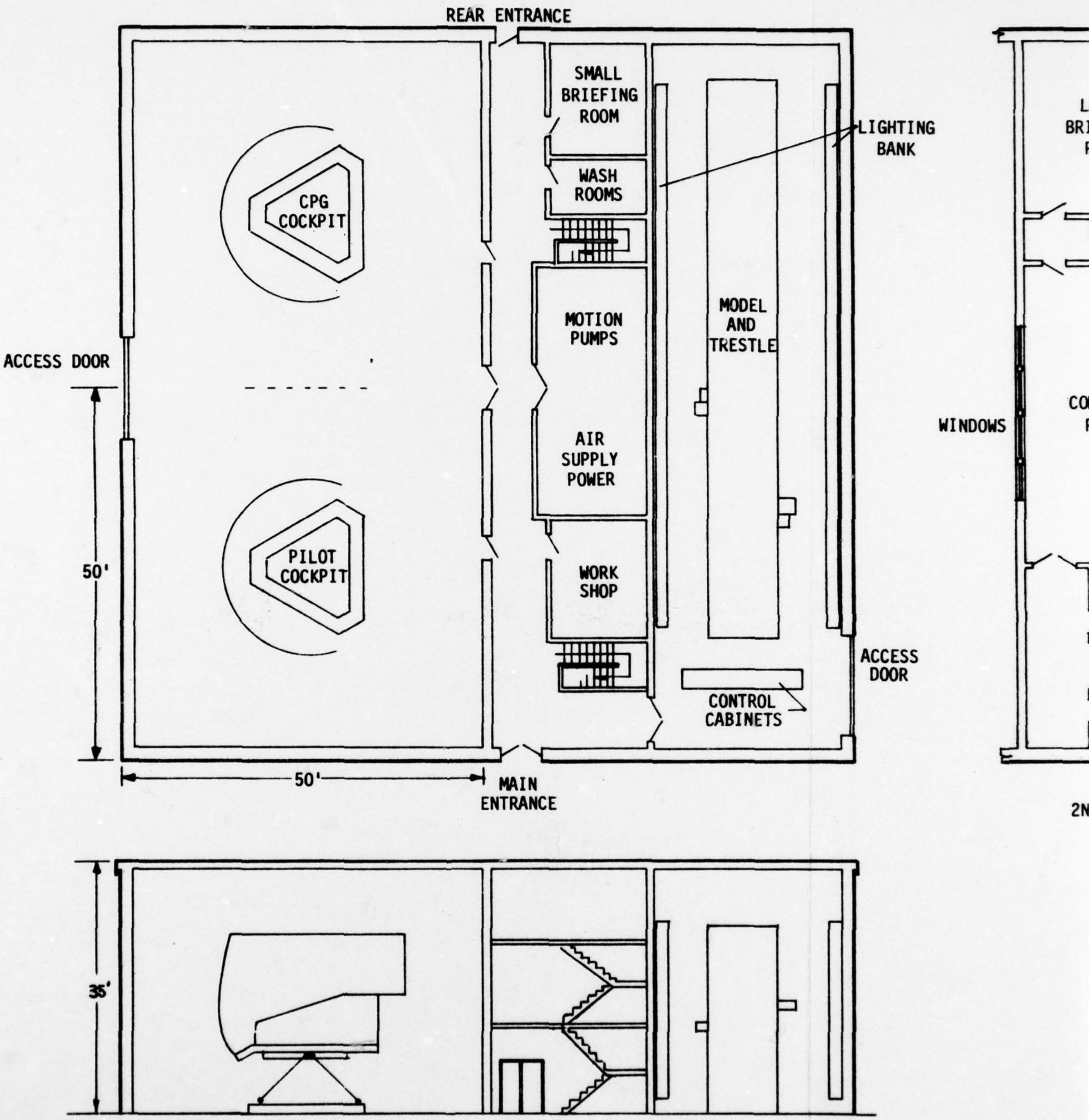
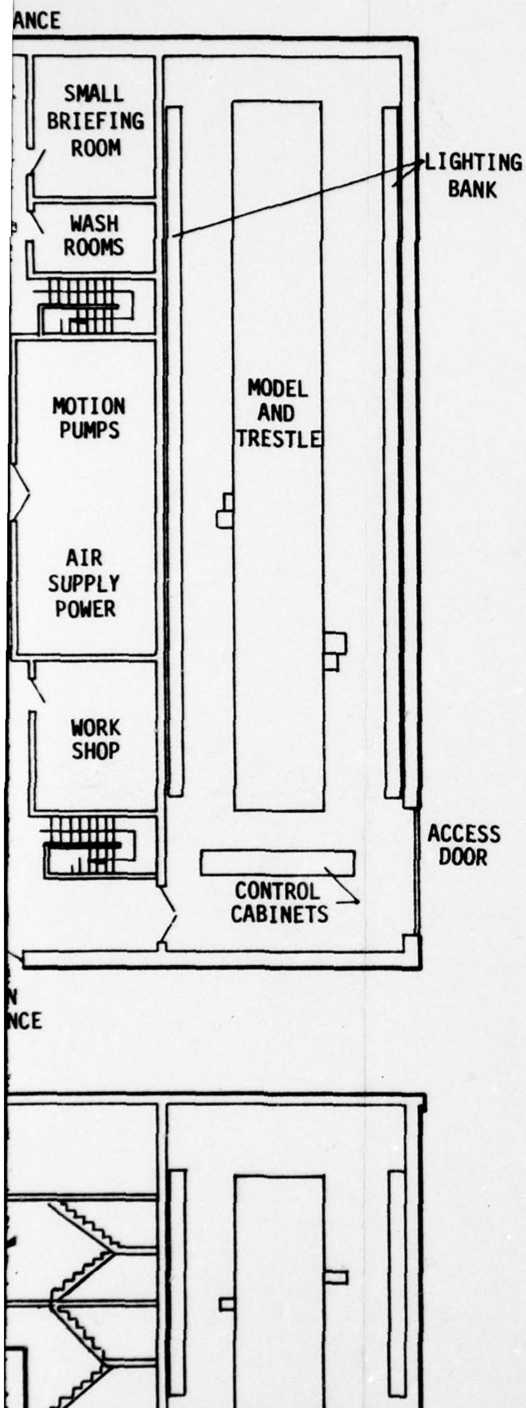
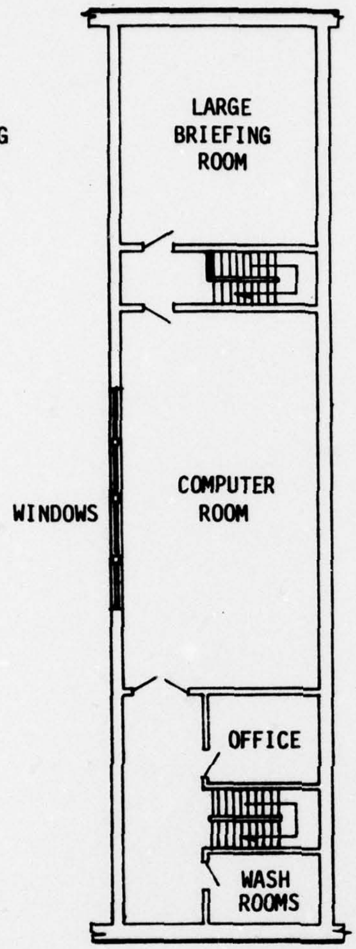
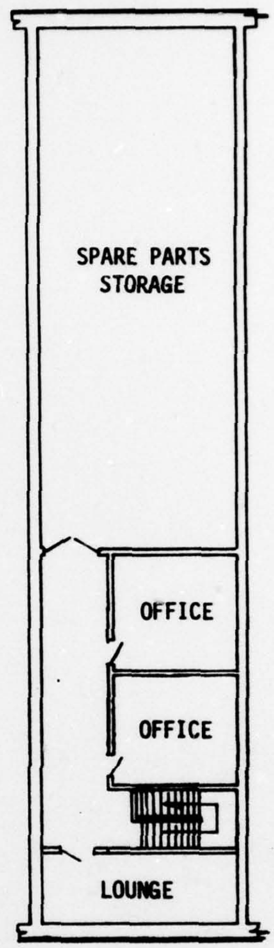



Figure 11-2. General Simulator Complex Layout




2ND FLOOR




3RD FLOOR

2

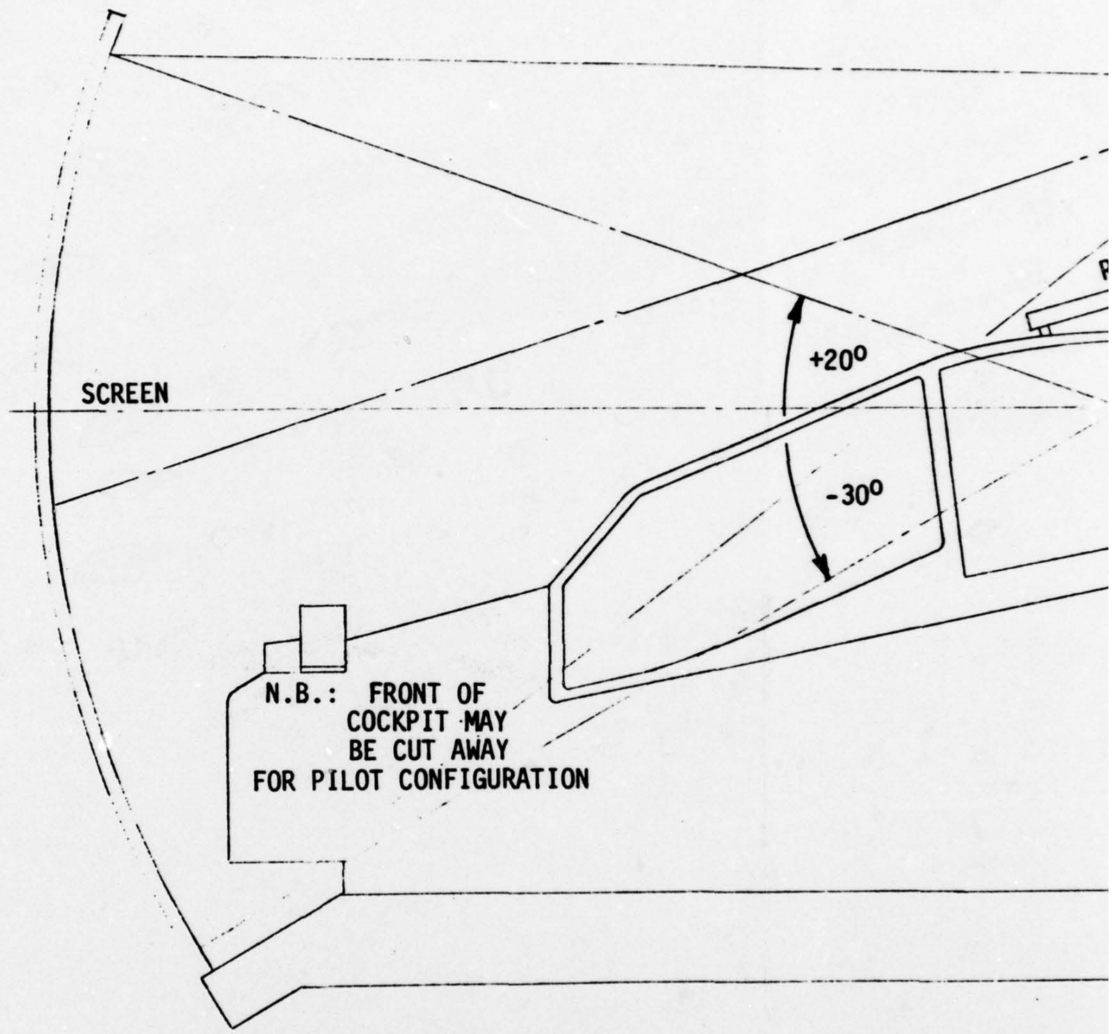
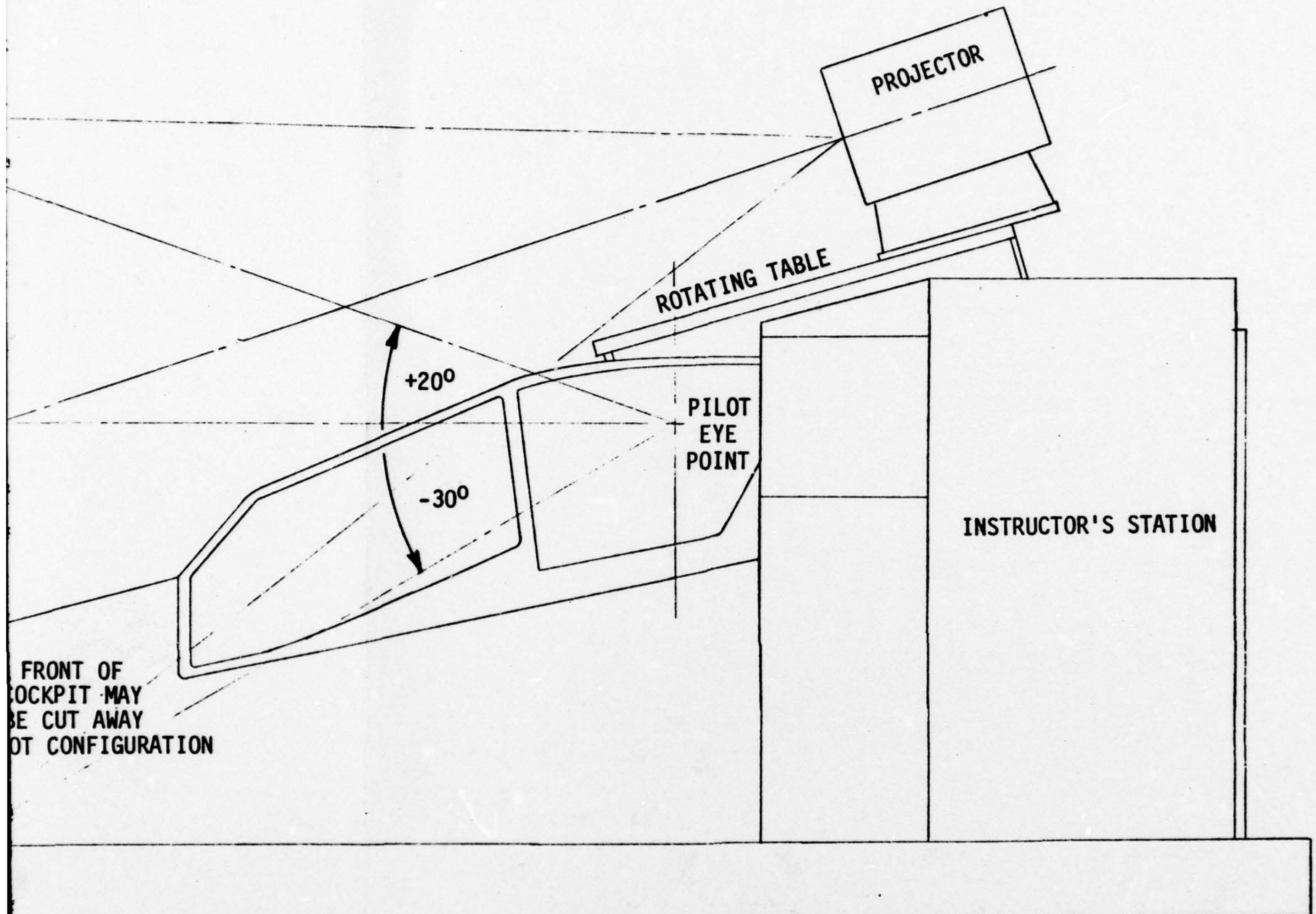



Figure 11-3. Pilot Cockpit Elevation


PROJECTOR
ROTATING TABLE
+20°
-30°
PILOT
EYE
POINT
INSTRUCTOR'S STATION
FRONT OF
COCKPIT MAY
BE CUT AWAY
OT CONFIGURATION

2

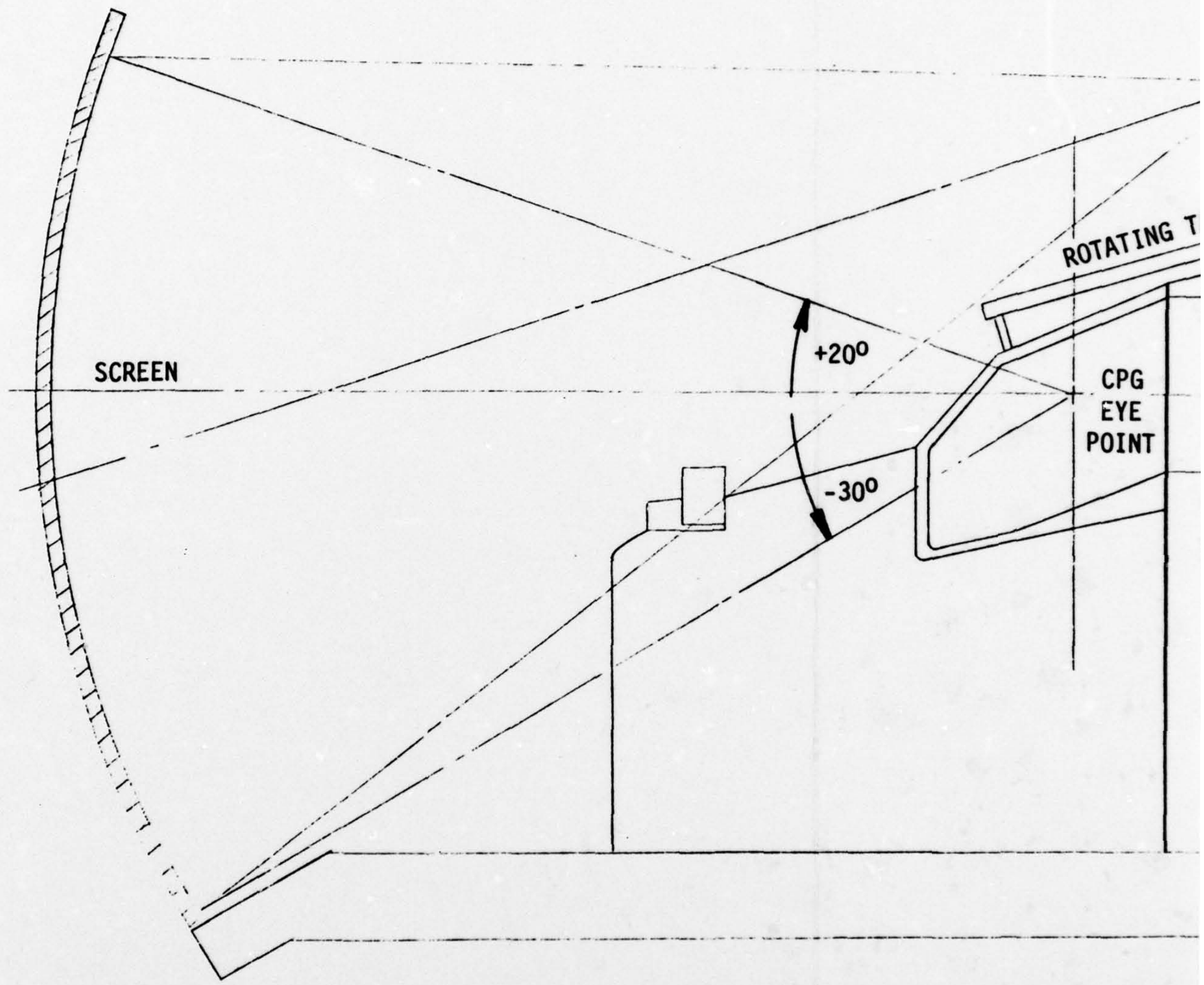
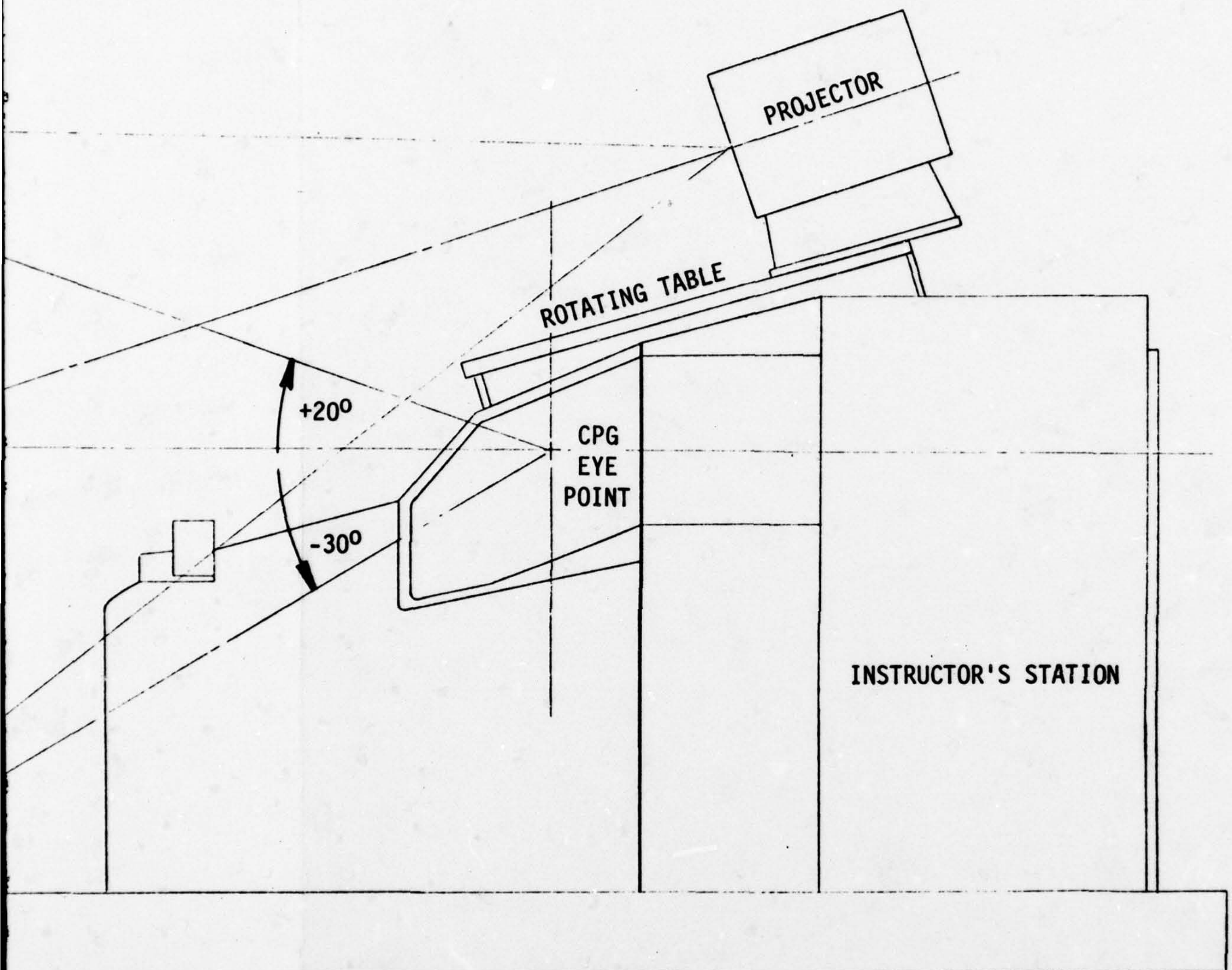



Figure 11-4. CPG Cockpit Elevation


PROJECTOR
ROTATING TABLE
+20°
-30°
CPG
EYE
POINT
INSTRUCTOR'S STATION

2

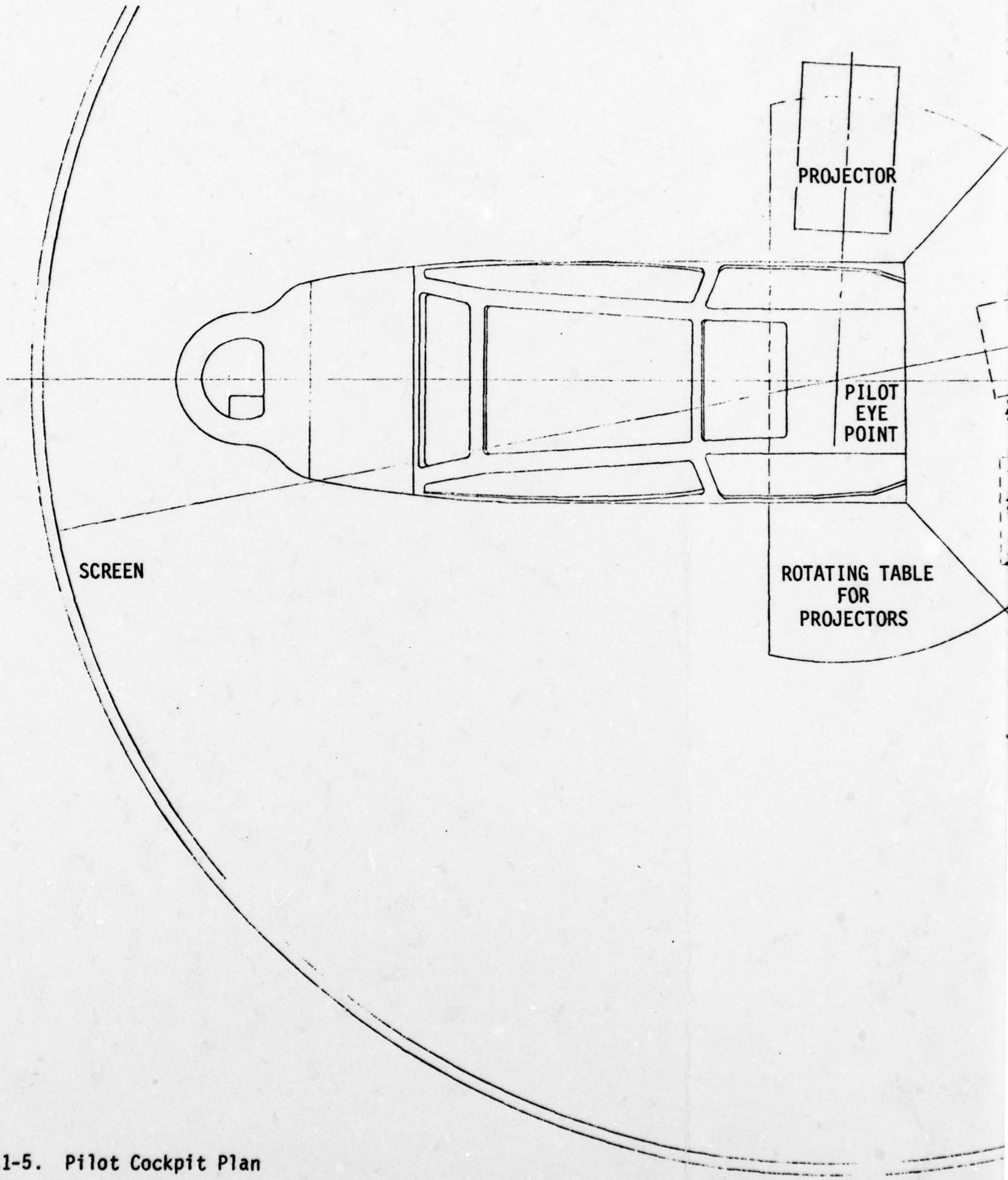
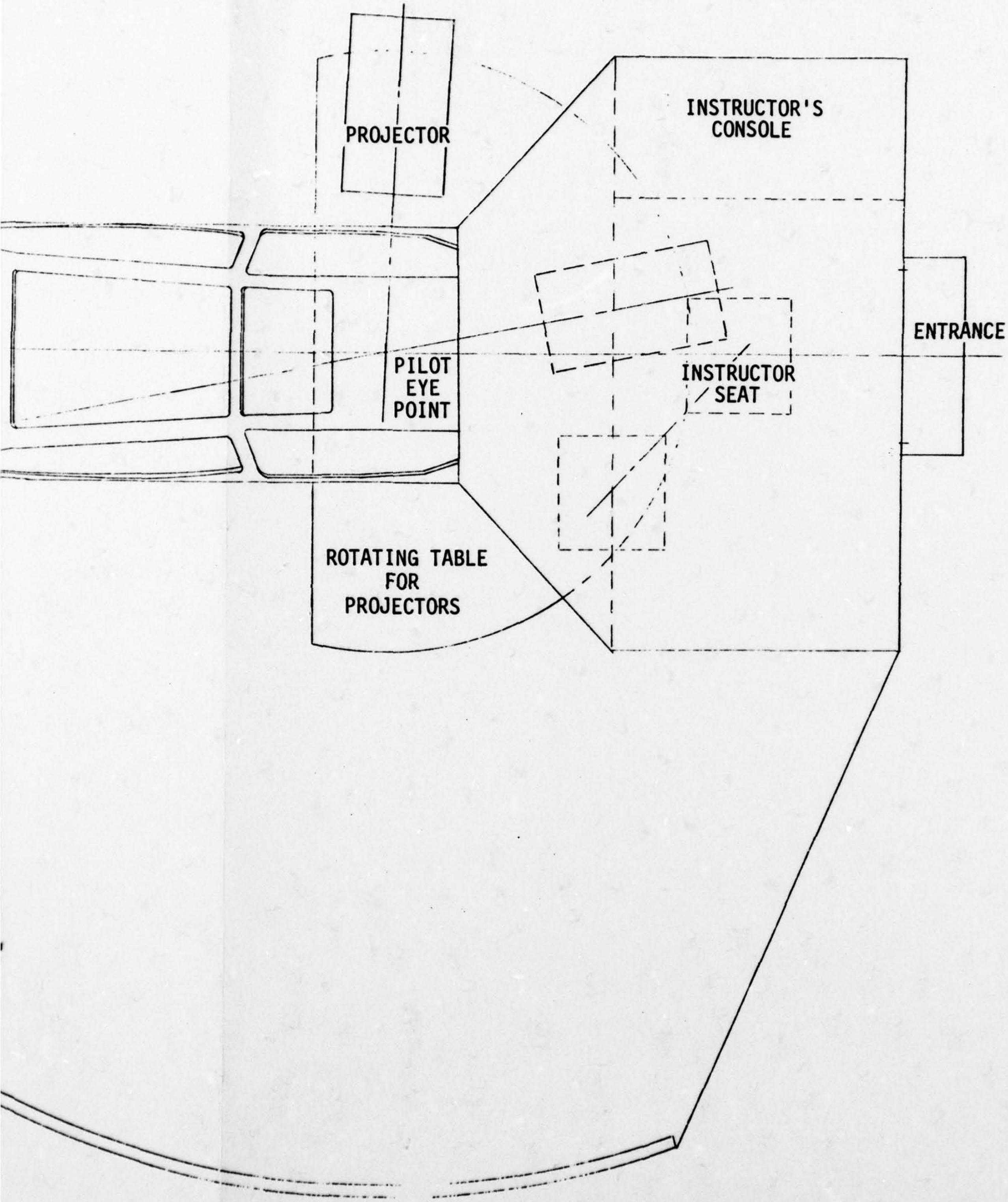



Figure 11-5. Pilot Cockpit Plan


PROJECTOR
INSTRUCTOR'S CONSOLE
ENTRANCE
PILOT EYE POINT
INSTRUCTOR SEAT
ROTATING TABLE FOR PROJECTORS

2

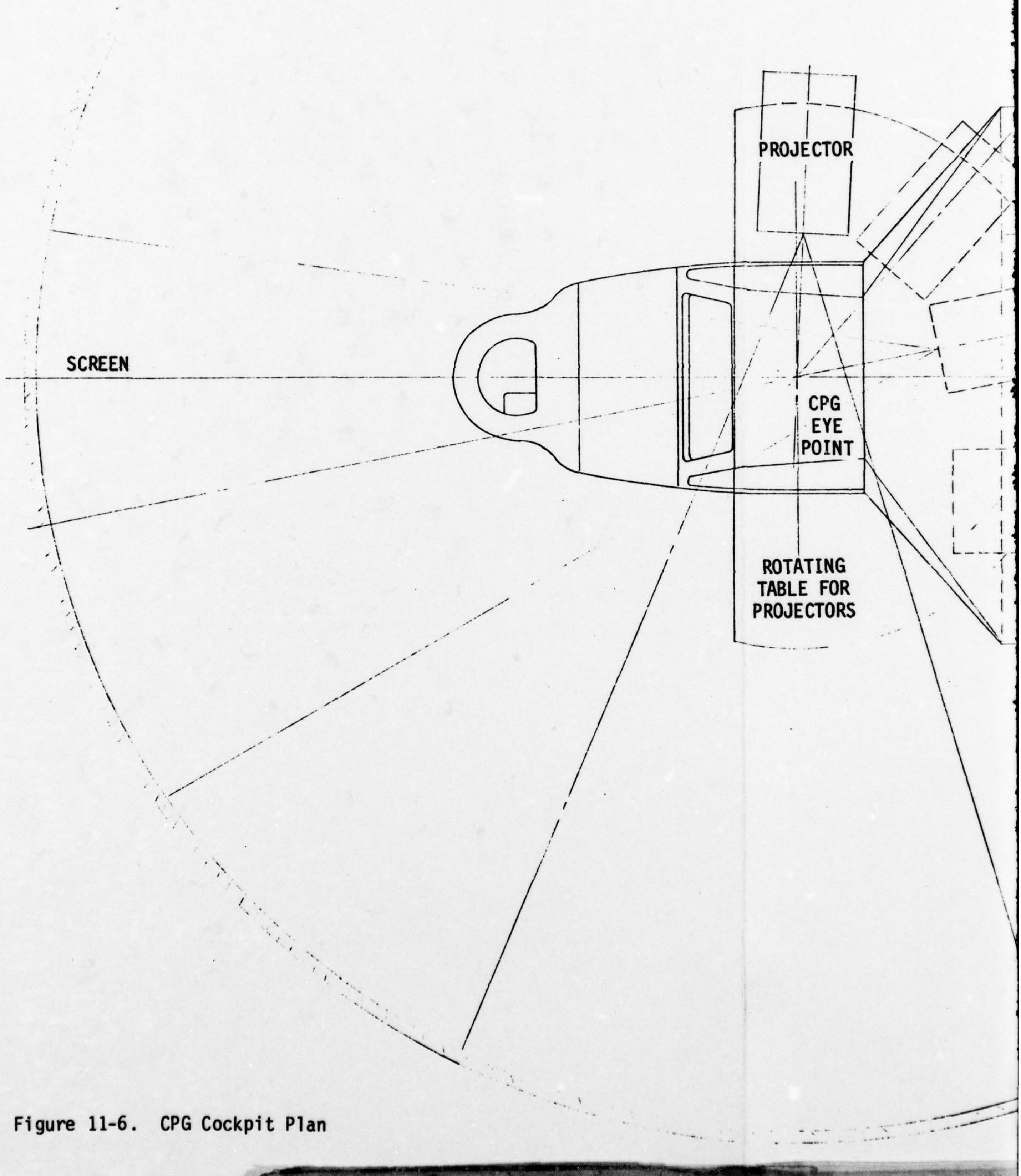
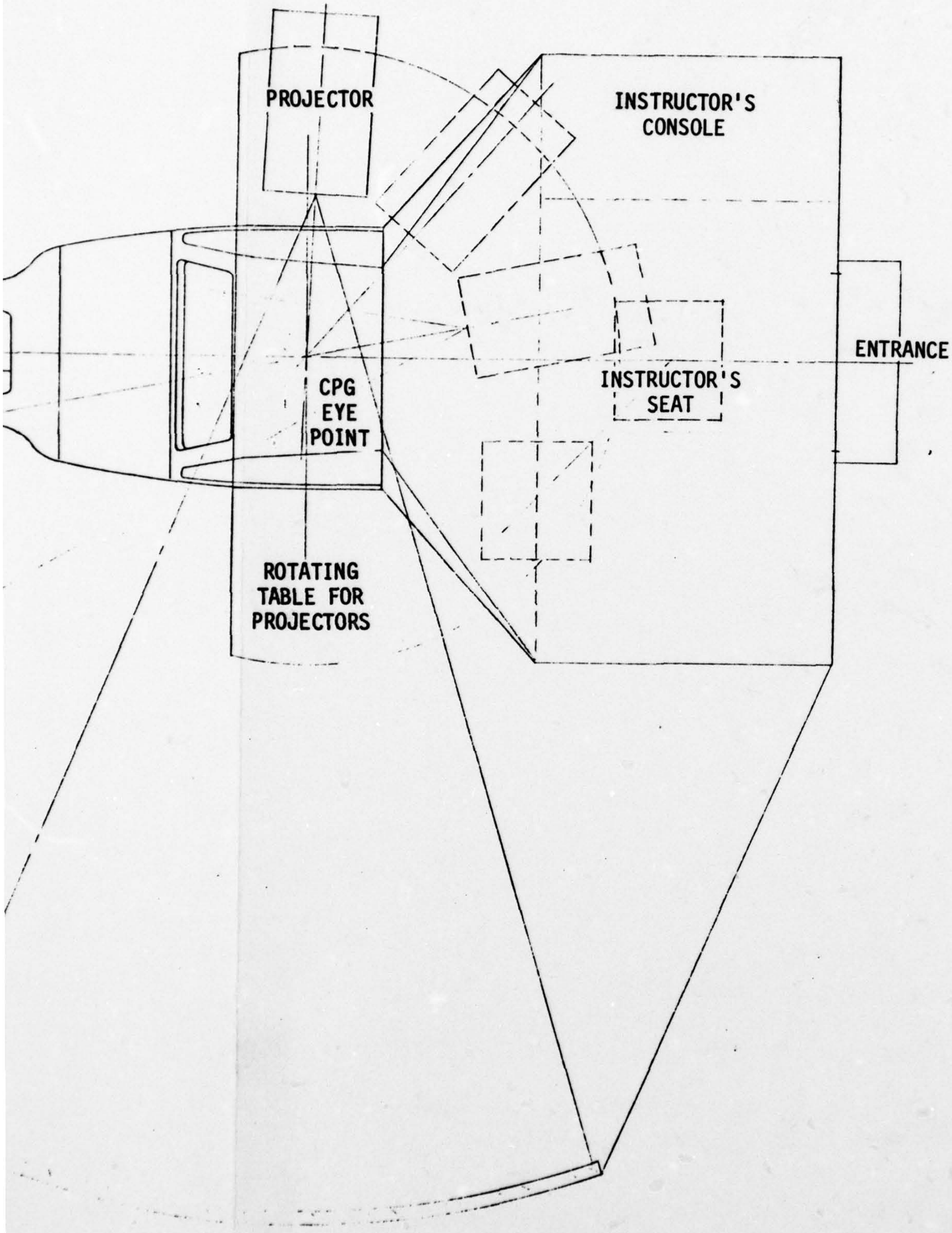



Figure 11-6. CPG Cockpit Plan


PROJECTOR
INSTRUCTOR'S CONSOLE
ENTRANCE
INSTRUCTOR'S SEAT
CPG EYE POINT
ROTATING TABLE FOR PROJECTORS

(c) Visual systems

. One 24-ft diameter spherical dome type screen on each cab, centered at the trainees eyepoint.

. Area of interest visual projection system using three field sequential CRT projectors mounted above each cab. The projectors can swivel as a unit horizontally $\pm 55^{\circ}$ and pitch $\pm 10^{\circ}$ to allow a $110^{\circ} \times 50^{\circ}$ instantaneously projected area to be placed anywhere within a total viewing area of $220^{\circ} \times 70^{\circ}$. Direction of projection is slaved to trainee head angles.

. Dual model board/CCTV visual generation system (identical for each cockpit) to provide 'out of the window' scene for the pilot and CPG, each having the following characteristics.

  . Three Isocon field sequential cameras.

  . One Farrand non-tilt probe.

  . Special effects generation equipment to superimpose rocket trails, missile trails, explosions, dust, etc., on visual scene.

  . 76-ft x 24-ft model board (identical for each system).

  . Insertion of scout helicopter on visual scene

. One Marconi Tepigen Computer Generated Image system used to generate infrared, TV and color images for the TADS and PNVS systems. The Tepigen has the following characteristics:

  . $2^{19}$ different textures which can be placed on any surface.

  . 3000 faces.

  . Capable of driving four separate channels.

  . Disc stored data base.

. TADS display via color monitor.

. High resolution targets in TADS display

. Government furnished equipment for the helmet mounted display systems.

(d) Aircraft equipment

. AH-64 fire control computer and symbol generator in the FWS.

. Aircraft instruments and panels wherever possible.

. Aircraft parts for control sticks and pedals.

. Radar Warning System display driven by simulation hardware.

(e) Computer system

. 2 x SEL 32/75 or Interdata 8/32 computers

. 2 moving head disc units

. 1 800-bpi magnetic tape transport

. ASR-35 teletype

. 300 cpm card reader

. 300 lpm line printer

(f) Interface

. Datapath C interface with on-line diagnostics capable of isolating faults to board level

. Incorporation of AH-64 Multiplex Bus system to allow use of aircraft equipment

(g) Instructors station

. Sanders Graphics 7 display generation system driving two 21-inch monitors at each instructor station

. Switches to allow fast access to commonly used functions

. Numeric keyboard

(h) Control forces

. Force feedback control force system electrically linking pilot and CPG stations

. Voltage controlled oscillator in load units to introduce vibration levels into the controls

(i) Alternative visual system using only computer generated imagery. Components are as follows:

- 'Area of interest' display system as in (c)
- 24-ft. diameter screen as in (c)
- 3 GE light valves mounted above each trainee's eyepoint giving a picture size $110^{o} \times 50^{o}$
- Projector swivelling mechanism as in (c)
- 3 Marconi Tepigen CGI systems used to generate the pilot and CPG 'out of the window' visual and infrared, TV and color images for the TADS and PNVS systems
- TADS display and targets as in (c)
- Helmet display as in (c)

11.2.2 <u>Performance</u>. The recommended AH-64 FWS includes accurate simulation of aircraft flight and equipment characteristics, high resolution visual displays and realistic motion cueing. The following paragraphs describe the principal performance features.

(a) Flight model - The AH-64 FWS flight model has the following characteristics:

- Accurate flight control and instrument responses throughout the total powered and unpowered flight envelope
- Accurate wind and turbulence modelling around ground profiles encountered during NOE flight
- Accurate control forces for the primary flight controls
- Full simulation of Automatic Stabilization Equipment
- Simulation of effect of C of G changes, icing effects, release of weapons, strike by enemy fire, and malfunctions on FWS handling characteristics

(b) Tactical systems - Simulation of AH-64 fire control system and weapons includes the following:

- Accurate simulation of missile, rocket and bullet trajectories
- Accurate simulation of laser range-finder/designator system
- Calculation of weapons hit and kill probabilities

(c) Navigation and communications systems - Simulation of AH-64 navigation and communication systems include the following:

- Simulation of over 1000 navigation and communication facilities placed anywhere in the world

- Calculation of Doppler navigation computer parameters for display and interfacing to fire control computer

- Use of prerecorded messages for communications

- On-line station editor for creation of new nav/com facilities

(d) Power plant and transmission - Simulation of the AH-64 power plant and transmission systems include the following:

- Accurate transient and steady state performance of T700-GE-700 power plant throughout the complete operating range

- Effect of gearbox losses and aerodynamic load on rotor transients and steady state operating point

(e) Systems - Systems simulation of the AH-64 includes accurate reproduction of characteristics of the APU, electrical system, hydraulic system, fuel system, brake system, anti-ice system, fire protection system and pressurized air system.

(f) Visual system - The recommended visual system for the AH-64 has the following performance characteristics:

- 'Out of the window' displayed resolution of six arc minutes

- 'Area of interest' display controlled by trainees head position

- Instantaneous FOV of $110^o \times 50^o$

- 'Area of interest' can be placed anywhere inside total viewing area of $220^o \times 70^o$

- Tepigen CGI system with texture generator for TADS and PNVS

- Special effects on 'out of the window' including rocket trails, smoke, explosions, rotor blades, fog, and dust clouds

- Flying area of 11 x 4 km, tactical playing area of 19 x 12 km

- Extended playing area using TADS to show scene outside flying area
- High resolution field sequential TV system provides low lag and superior dynamic resolution with no registration problems
- Realistic simulation of night illumination levels
- Detailed large scale model permits realistic NOE operation with probe protection done through software

(g) Motion system modules - The recommended motion system modules for the AH-64 FWS have the following characteristics:

(1) Seat shaker system

- Vibration in the vertical mode, encompassing frequencies from one to four times the normal operating rotor speed
- Two frequencies of independently controlled amplitude available simultaneously
- Amplitude and frequencies software controlled as a function of flight condition, control position and malfunctions of engine and transmission

(2) G-Seat

- Inflatable seatpan and backrest cells
- Cell pressure controlled by software drive equations as a function of translation acceleration

(3) Cockpit motion system

- Position command system with pressure feedback providing optimum high bandpass performance with high level of smoothness
- Comprehensive safety system consisting of:
  - Mechanical safety factor
  - Fail safe geometry
  - Hydraulic safety cushions

- Electronic failure detection system
- Software drive equation optimized for individual cue generation for pilot and copilot/gunner

(h) Instructor facilities - The instructor facilities recommended for the AH-64 FWS include the following features:

- Capability to allow one instructor to supervise both crew members
- Lesson plan system to allow automated or semi-automated progression through an FWS training mission
- Record and playback for up to 30 minutes of selected training mission. Activation can be automatic through lesson plan or direct by instructor
- CRT page and graphics formats
- Minimum number of actions to access facilities through use of page and line select buttons
- Up to 300 minutes of maneuver demonstration
- Off-line creation of tactical scenario using either joystick and color CRT to simulate target viewpoint when creating track, or using instructor CRT and tracing routes on a contour map display
- CRT maps showing position and trace of all mission vehicles on a contour type display
- Automated tactical evaluation of crew performance in acquiring and destroying targets and surviving in a hostile environment.

## 11.3 AH-64 FWS FACILITY CONSIDERATIONS

11.3.1 FWS Space Requirements. A plan view of the envisaged complex for the recommended AH-64 FWS is shown in Figure 11-2. For the alternative system using only CGI visual a model board room is unnecessary which reduces the overall building size, although a larger computer room area is needed to house extra electronic cabinets. Room sizes for both configurations are given in Table 11-1 and indicate a total building space saving of about 100,000 cubic feet using only CGI generation methods.

11.3.2 FWS Trainer Power Requirements. Table 11-2 shows the electrical power needed to operate both AH-64 configurations. As expected the power needed to run the model board/CCTV system is substantially higher than for the CGI configuration which is due primarily to the power required to drive the model board illumination lighting.

TABLE 11-1. AH-64 FWS FACILITY ROOM SIZES

| Name | Dual Model Board/CCTV Room Size | | CGI Visual | | |
|---|---|---|---|---|---|
| | Ht | Floor Area | Ht | Wdth | Lngth |
| Pump room | 10 | 12 x 24 | 10 | 12 | x 24 |
| Computer room | 10 | 30 x 20 | 10 | 30 | x 20 |
| Flt compts room | 35 | 50 x 100 | 35 | 50 | x 100 |
| Visual room | 35 | 30 x 84 | - | - | |

TABLE 11-2. AH-64 FWS TRAINER POWER REQUIREMENTS

| | Two Model Board/CCTV M | CGI Visual |
|---|---|---|
| Motion | 80 kw | 80 kw |
| Flt compartment (including computer, interface) | 30 kw | 30 kw |
| Visual | 496 kw | 126 kw |
| Total power | 606 kw | 236 kw |

11.3.3 Cooling Requirements. In studying the cooling requirements we calculated the heat generated by simulator equipment in each room, took the average temperatures at Fort Rucker over three periods of four months each, and calculated heat transfer through an average building to give the heating and cooling requirements for each period. We then studied cooling techniques designed to save energy and calculated the total power requirements of the preferred systems.

11.3.3.1 Model Board/CCTV Configuration Facility Cooling. In the model board/CCTV FWS configuration facility the only requirement for heating is in the flight compartment room where an input of 34,000 BTUs is needed to maintain 72°F in winter. As the operating temperature in the computer room should also be 72°F, it appears reasonable to extract the warm air from the computer room and vent it into the flight compartment for heating purposes. In the middle period when only cooling is required it would be best to ventilate the flight compartment area with outside air. The computer room will have to use air conditioning as ventilation of the computer room would require an airflow of 12,000 cubic feet per minute (CFM) which is excessive. In the summer period it will be necessary to use air conditioning for both these areas because the high outside temperature precludes any ventilation.

The heat to be dissipated is greatest in the visual room although we believe ventilation using outside air during the cooler seasons could be used to remove a large quantity of heat. An air flow of 25,000 CFM would be required in winter to keep the temperature at 85°F in the visual room which would increase to 50,000 CFM in the middle period. As 50,000 CFM is quite high and would involve considerable drafts it would probably be best to switch to air conditioning during the middle period.

The pump room operating temperature is not important and we believe the use of a ventilating fan will suffice throughout the year.

Considerable cooling power is saved through the use of ventilation rather than air conditioning as is shown in the figures in Table 11-3.

11.3.4 CGI Configuration Facility Cooling. With an all CGI FWS configuration the heat to be dissipated in the computer room is greatly increased by the presence of three sets of CGI equipment. In the winter period it would not be possible to use outside air ventilated because the flow required would be excessive. Air could be circulated to heat the flight compartment room but the remaining heat would have to be removed by air conditioning.

During the late middle and summer periods it would be necessary to switch entirely to air conditioning again because of the high ventilation rates required through the small computer room area.

The pump room would again utilize a ventilating fan all year round as the operating temperature in that area is not important.

Power requirements for this configuration are shown in Table 11-4.

11.3.5 Cooling Water Supply. In addition to facility cooling, an air conditioning unit is used to supply flight compartment comfort cooling and heat is removed from the hydraulic pumps needed to drive the 6-degree of freedom motion systems using an oil/water heat exchanger. The heat from these systems is removed by a cooling water supply which must in turn be cooled either by a conditioning unit or by way of a water cooling tower. The latter method is by far the least expensive but can only be used in the lower temperature and humidity seasons and not in summer.

TABLE 11-3. AH-64 FWS MODEL BOARD/CCTV CONFIGURATION COOLING REQUIREMENTS

| | Summer (81°F) | Middle (59°F) | Winter (37°F) |
|---|---|---|---|
| Computer Room (72°F) | | | |
| Heat to be dissipated (BTU) | 172,600 | 168,700 | 164,800 |
| Type of cooling | A/C | A/C | Vent |
| Airflow (CFM) | - | - | - |
| Power required (kW) | 17 | 16.5 | 1 |
| Flight Compartment (72°F) | | | |
| Heat to be dissipated (BTU) | 56,000 | 11,000 | -34,000 |
| Type of cooling/heating | A/C | Vent | Vent from comp room |
| Airflow (CFM) | - | Low | 4,000 |
| Power required (kW) | 5.5 | 1 | 1 |
| Model Board Room (85°F) | | | |
| Heat to be dissipated (BTU) | 1,345,600 | 1,321,400 | 1,300,000 |
| Type of cooling | A/C | A/C | Vent |
| Airflow (CFM) | - | - | 25,000 |
| Power required (kW) | 131 | 129.5 | 3.2 |
| A/C Water Supply | | | |
| Type of cooling | A/C | Tower Cooling | Tower Cooling |
| Power required (kW) | 20 | 1 | 1 |
| Pump Room Ventilation Power (kW) | 1 | 1 | 1 |
| Total Power (kW) | 174.5 | 149 | 7.2 |

Average Power Consumption = 110.2 kW

TABLE 11-4. AH-64 FWS CGI CONFIGURATION COOLING REQUIREMENTS

| | Summer (81°F) | Middle (59°F) | Winter (37°F) |
|---|---|---|---|
| Computer Room (72°F) | | | |
| Total heat to be dissipated (BTU) | 447,000 | 443,700 | 440,000 |
| Type of cooling | A/C | A/C | A/C/CIRC |
| Airflow (CFM) | - | - | - |
| Power required (kW) | 43.6 | 43 | 40 |
| Flight Compartment Room (72°F) | | | |
| Total heat to be dissipated (BTU) | 56,000 | 11,000 | -34,000 |
| Type of cooling | A/C | Vent | Circ |
| Airflow (CFM) | - | Low | Low |
| Power required (kW) | 5.5 | 1 | 1 |
| Pump Room Ventilation Power (kW) | 1 | 1 | 1 |
| A/C Water Power Supply | | | |
| Type of cooling | A/C | Tower Cooling | Tower Cooling |
| Cooling power (kW) | 20 | 1 | 1 |
| Total power (kW) | 70.1 | 46 | 24 |

Average power consumption = 46.7 kw

The estimated power needed to remove this heat is included in Tables 11-3 and 11-4.

11.3.6 Total Facility Power Requirements. The total facility power required to operate the simulator and the cooling equipment is calculated by adding the trainer operating power and the facility air conditioning power. The results can be found in Table 11-5. These figures are used in the cost effectiveness analysis in Paragraph 11.7.

TABLE 11-5. AH-64 TOTAL POWER REQUIREMENTS

| | Total Power Requirements |
|---|---|
| Two Model Board/CCTV (kW) | 716.2 |
| All CGI (kW) | 282.7 |

## 11.4 RELIABILITY AND MAINTAINABILITY

The reliability and maintainability predictions shown in Figure 11-7 describes the projected performance of the AH-64 FWS for the recommended and alternative visual generation equipment alternatives. More details on these figures can be found in Appendix H.

The calculations in this analysis treat each system and element of each system as a series chain hence any failure is reflected in the failure rate of the total system. The model used includes design and components to best commercial standards.

Factors concerning the R&M predicting are as follows:

- Line printer and card reader are excluded from Figure 11-7 figures because they do not normally operate during training
- Motion system figures are based on information on the 6-degree of freedom motion system used by the USAF on F15 simulators
- Visual camera tubes have been lifted at 3000 hours and do not appear in the figures
- GE light valve and Grumman CRT projectors have been given the same failure rate and are lifed at 3000 and 1500 hours respectively
- The estimate of Tepigen failure rates and MTTR's are based on the GE Compuscene system
- Failures of aircraft parts including instruments, panels and other equipment are taken from the AH-64 system spec. and are included in the model.

The figures demonstrate that the AH-64 FWS with the 2 Model Board visual system has the higher MTBF and lower MTTR of the two alternatives and allows an availability of 97.7%. We feel that the R & M predictions do not reflect the redundancy features and criticality of failures in the simulator. This is particularly true in the case of the CGI system where spare channels are available for picture output meaning higher availability through redundancy. Also, the loss of an instructors button or CRT, the loss of motion systems, or the failure of an instrument would not disallow the continuance of a training mission.

## 11.5 DESIGN AND MANUFACTURING STANDARDS

CAE standard manufacturing processes and procedures conform to military specifications for both military and commercial products. However, flight simulators for both military and commercial customers normally make considerable use of high quality commercial components in order to exploit the most advanced available technology. We believe that simulators produced using CAE's current design and manufacturing standards have proven equally or more reliable than competitive equipment built strictly to military standards.

The design and manufacturing standards currently employed by CAE have proven effective in achieving over 99% availability on installations operating 20 hours/day, 7 days/week for a total of 7000 training hours/annum. This has been achieved by using high quality commercial parts and manufacturing standards, and through a high standard of electrical and mechanical design.

We believe that the incorporation of off-the-shelf high quality standard commercial items such as power supplies, motion system, interface, computer systems and visual systems would give equivalent performance and sufficient reliability to negate possible benefits of redesigning proven and tested equipment to different standards.

## 11.6 AH-64 COSTS AND SCHEDULE OF PRODUCTION

The FWS costs for procurement reflect the design to military standard of all components apart from computer and visual systems. This is because we believe that these conditions will apply to the design and development of the AH-64 FWS and that relaxation of this requirement is unlikely to be permitted.

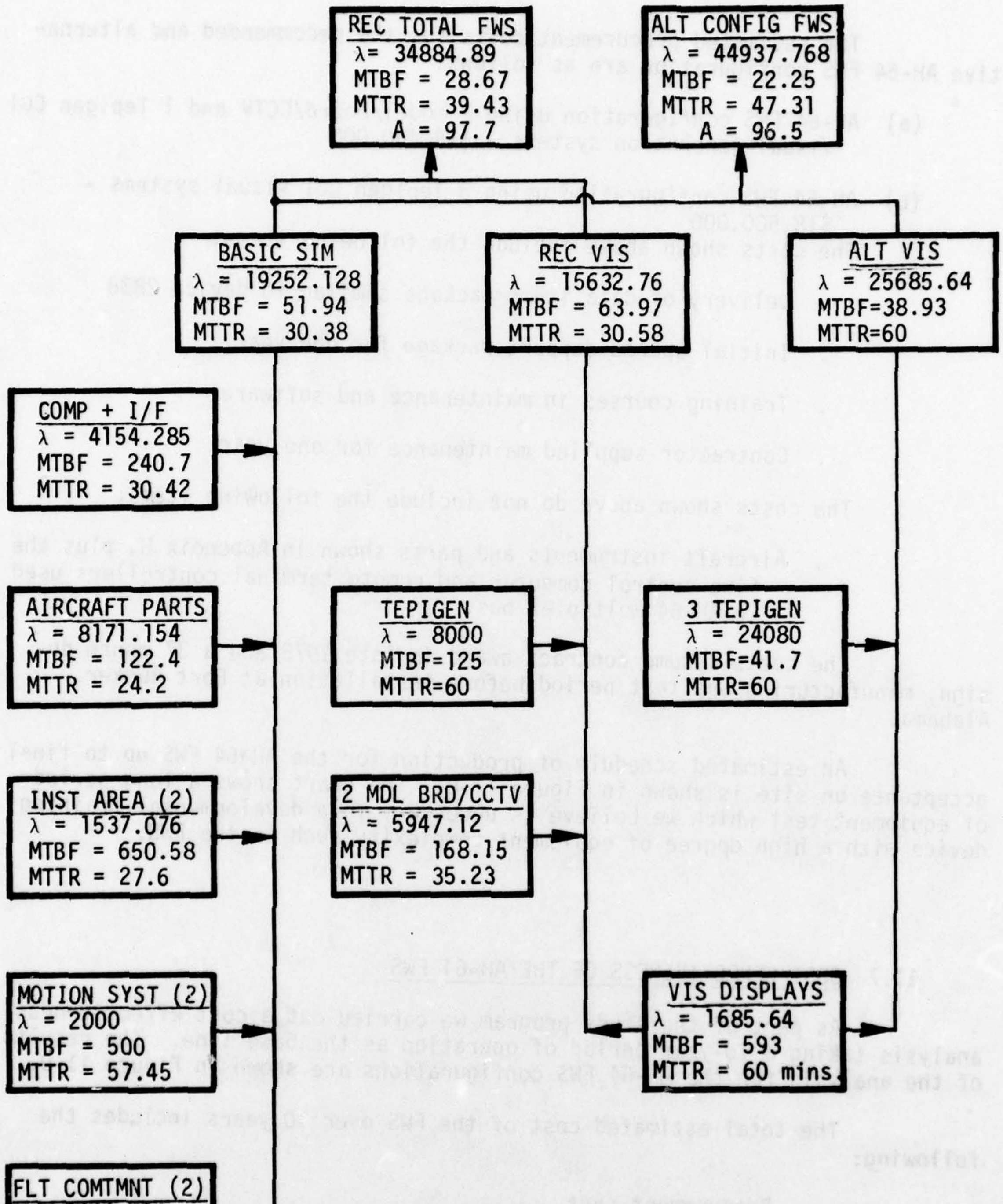



Figure 11-7. Reliability and Maintainability Predictions

The estimated procurement costs for the recommended and alternative AH-64 FWS configuration are as follows:

(a) AH-64 FWS configuration using 2 model/board/CCTV and 1 Tepigen CGI visual generation systems - $18,460,000

(b) AH-64 FWS configuration using 3 Tepigen CGI visual systems - $18,500,000

The costs shown above include the following items:

. Delivery of data items package similar to device 2B38

. Initial spares support package for one year

. Training courses in maintenance and software

. Contractor supplied maintenance for one year

The costs shown above do not include the following items:

. Aircraft instruments and parts shown in Appendix G, plus the fire control computer and remote terminal controllers used in AH-64 multiplex bus.

The costs assume contract award in late 1978 and a 37 month design, manufacturing and test period before installation at Fort Rucker, Alabama.

An estimated schedule of production for the AH-64 FWS up to final acceptance on site is shown in Figure 11-8. The chart shows a long period of equipment test which we believe is necessary in a developmental training device with a high degree of equipment complexity such as the FWS.

## 11.7 COST-EFFECTIVENESS OF THE AH-64 FWS

As part of the study program we carried out a cost effectiveness analysis taking a 10-year period of operation as the base line. The results of the analysis for the AH-64 FWS configurations are shown in Figure 11-9.

The total estimated cost of the FWS over 10 years includes the following:

. Procurement cost

. Ballpark estimates for the cost of spares support of over 10 years

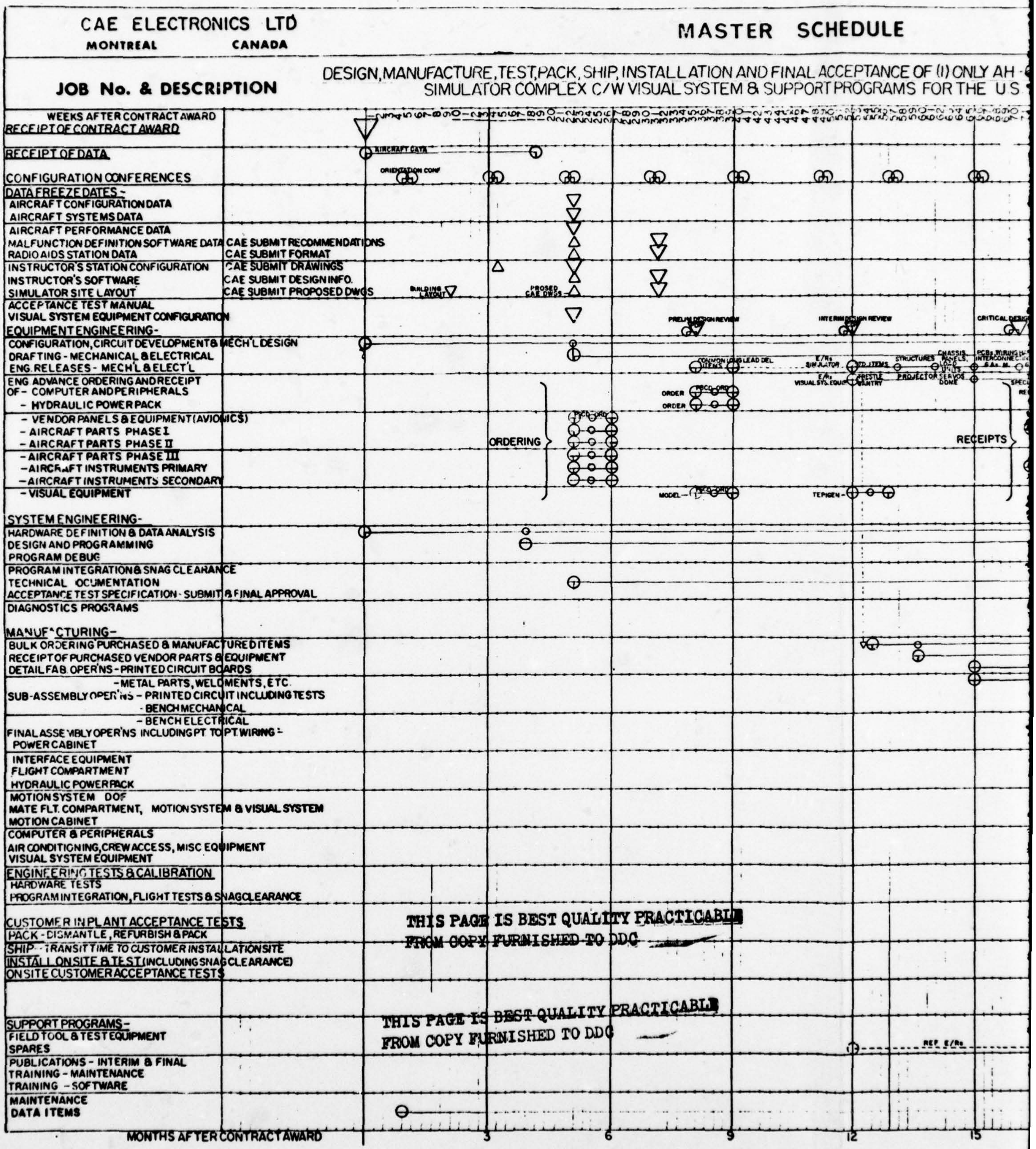






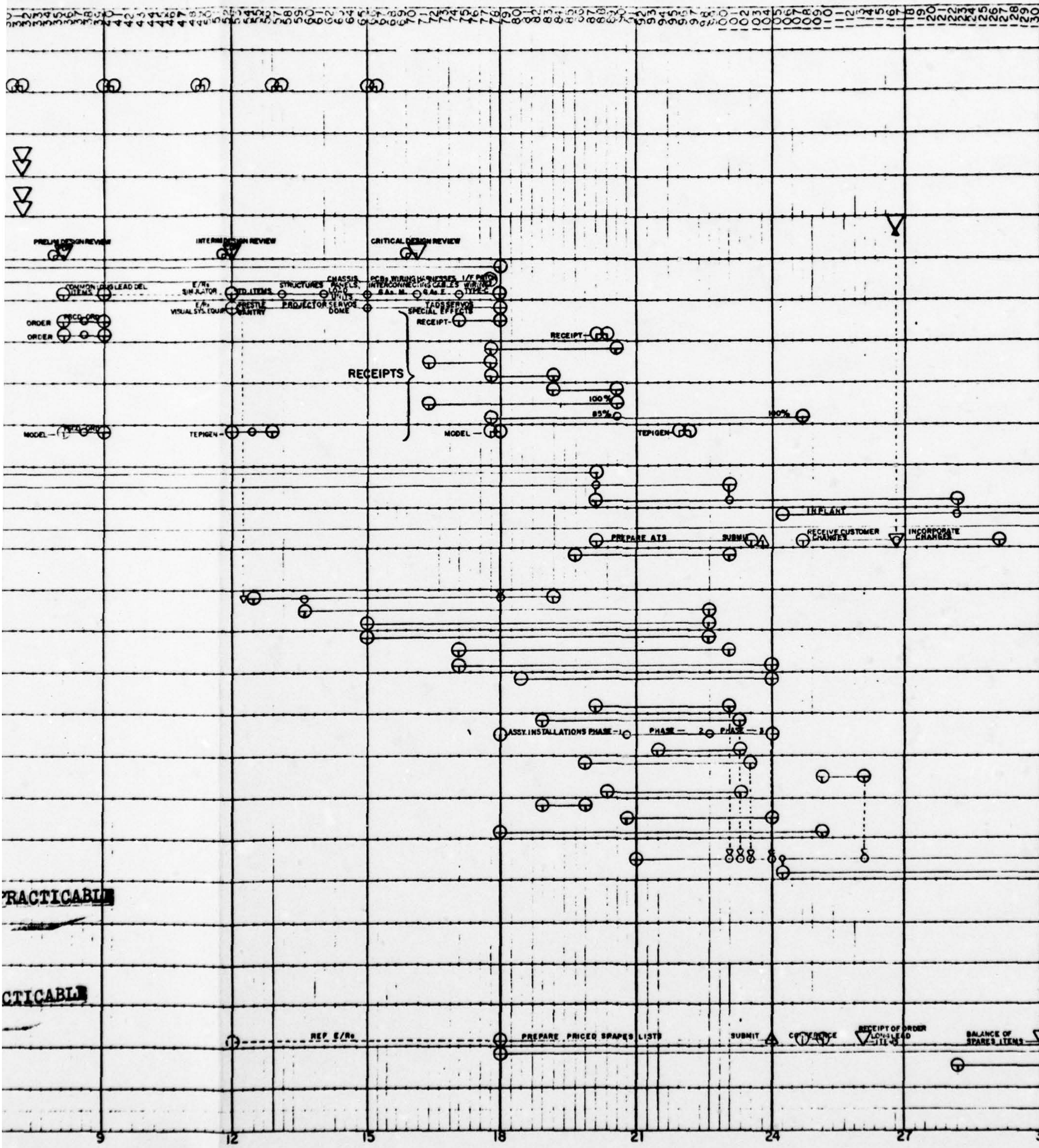

Figure 11-8. Estimated Schedule of Production (Sheet 1 of 2)

## MASTER SCHEDULE

SHT. I CONT'D ON SHT. 2

ITALLATION AND FINAL ACCEPTANCE OF (I) ONLY AH-64 HELICOPTER FLIGHT AND WEAPONS
SUAL SYSTEM & SUPPORT PROGRAMS FOR THE U.S. ARMY, FORT RUCKER, ALABAMA.

DATE 26 SEP. 1977



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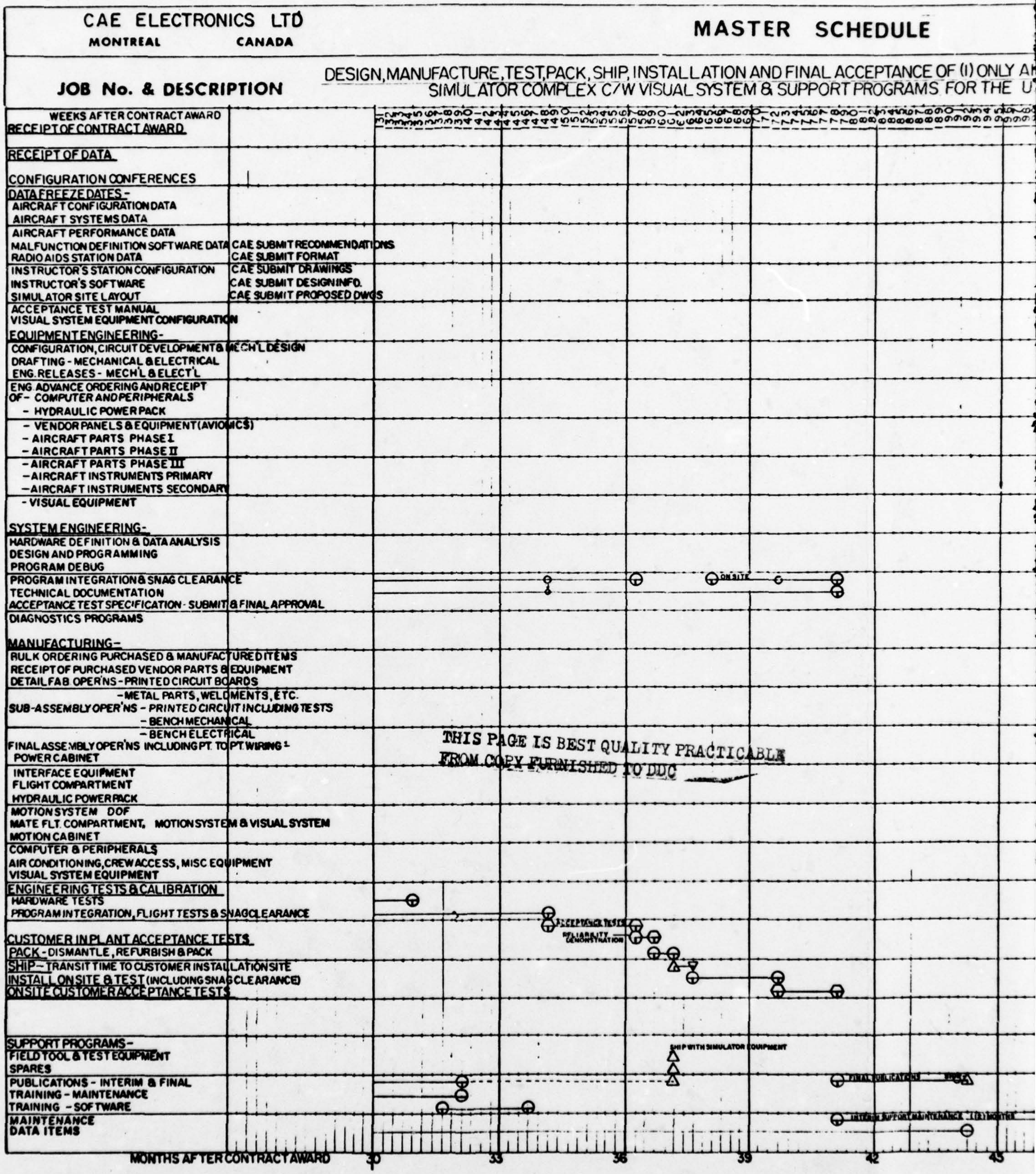


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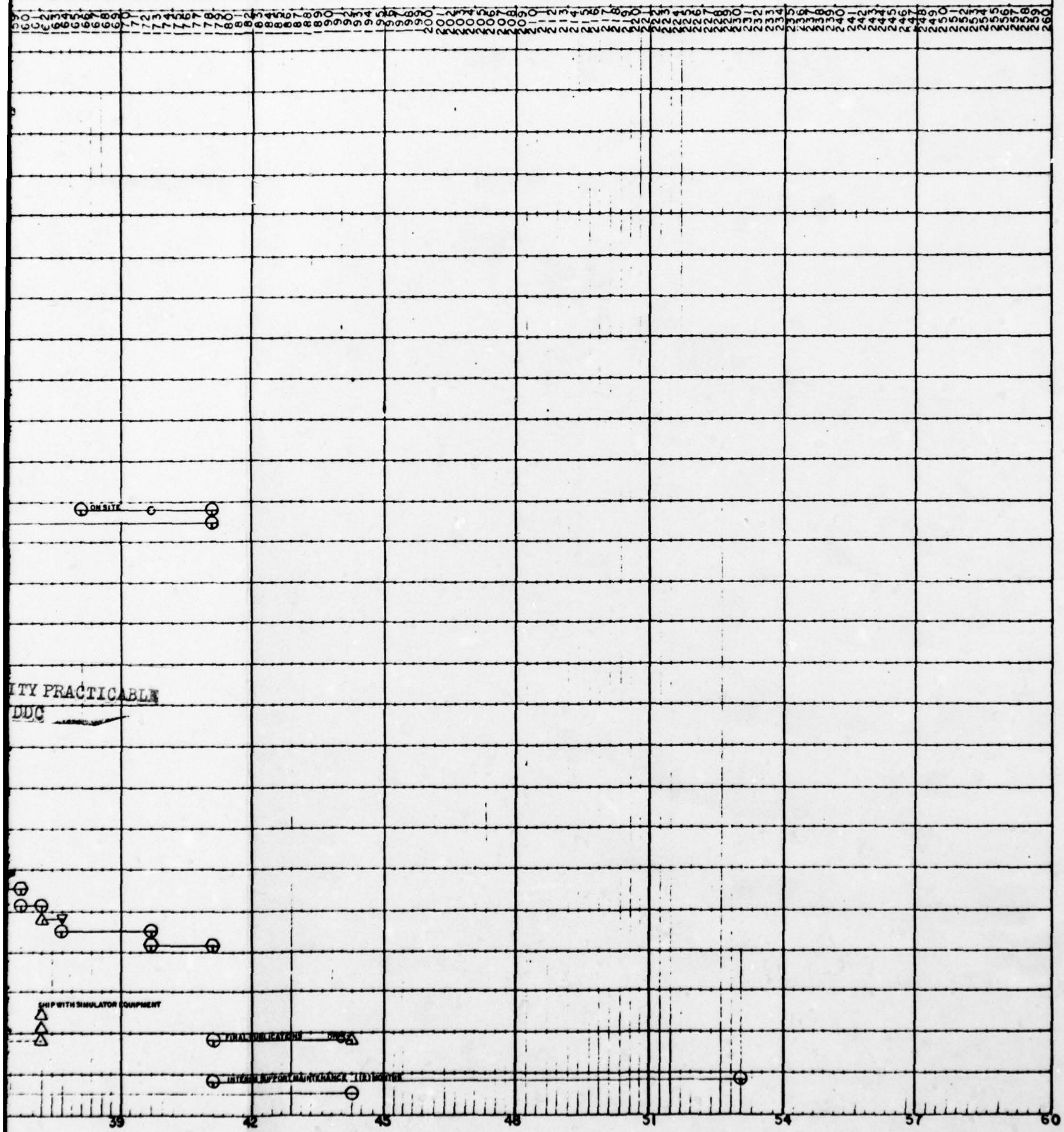
Figure 11-8. Estimated Schedule of Production (Sheet 2 of 2)

## MASTER SCHEDULE

SHT. 2 FINAL

STALLATION AND FINAL ACCEPTANCE OF (I) ONLY AH-64 HELICOPTER FLIGHT AND WEAPONS
ISUAL SYSTEM & SUPPORT PROGRAMS FOR THE U.S. ARMY, FORT RUCKER, ALABAMA.

DATE 26 SEP. 1977






2

- Estimated cost of electrical power using the total power estimated in Table 11-4

- An estimated cost for a 4-man maintenance team for 10 years

One of the most interesting factors when examining the comparative cost of the model board and CGI alternatives is the estimated cost of spare parts. The principal difference is in the cost of projection systems, where the cost of the proposed GRUMMAN CRT projector is substantially less than the cost of a GE light valve. The projection devices are lifed at 1500 and 3000 hours respectively, requiring an average annual use of 20 CRT projector tubes or 10 GE light valves. Assuming replacement unit costs of $1000 and $14000 the annual costs of both systems are $20,000 and $140,000 respectively which over 10 years results in a considerable saving with a field sequential CCTV system.

The total costs do not include the cost of the simulator building or the cost of instructor/pilot time during training. We believe that the amount of instruction time used by instructor/pilots will not be greater on the FWS than it would be on the aircraft (probably less) and so the cost can be omitted.

The cost of training/hour for both configurations was obtained using the available training hours over 10 years calculated from the predicted availability in Figure 11-7 at a scheduled 5000 hours/annum.

The basic cost of operation of the AH-64 has been estimated at $1030/hour by PM TRADE and costs of weapons are estimated at $8/30 mm round and $10,000 for one Hellfire missile. If we assume that during a training mission lasting one hour a trainee crew release a full complement of 16 Hellfire missiles then the cost of crew mission training in the AH-64 could cost over $160,000/hour if real weapons are used.

As the total cost of the recommended AH-64 FWS is only $489/hour, it will produce savings of over $500/hours for transition training and considerably more for AH-64 crew mission training involving the extensive use of weapons.

| | Recommended AH-64 FWS with 2 Model Board/CCTV Visual Systems and 1 Tepigen CGI System | Alternative AH-64 FWS with 3 Tepigen CGI Systems |
|---|---|---|
| Estimated FWS cost * | $18,460,000 | $18,500,000 |
| Estimated spares for 10 years | 2,500,000 | 2,550,000 |
| Estimated cost of power for 10 years @ 4¢/kw hr. | 1,432,400 | 565,400 |
| Estimated cost of maintenance team for 10 years | 1,500,000 | 1,500,000 |
| Total cost over 10 years | $23,892,400 | $23,115,400 |
| Predicted availability | 97.7 | 96.5 |
| Hours training in 10 years at scheduled 5000 hours/annum | 48,850 | 48,250 |
| Cost of training/hour | $489 | $479 |

* Does not include aircraft parts, instruments, avionics, fire control computer and building costs.

Figure 11-9. Cost Effectiveness Analysis

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APPENDIX A

AH-64 TRAINING TASK ANALYSIS

## A.1 INTRODUCTION

The training task analysis was taken to define as accurately as is possible at this time the tasks required in AH-64 crew training prior to design of the FWS.

The AH-64 training tasks were defined by adapting an AH-1 training task list, issued by the U.S. Army Armor School at Fort Knox, to reflect differences in equipment and usage between the AH-1 and the AH-64. The AH-64 training task list forms the left hand column of the task analysis in (Table A-2) and is broken into groups of similar training tasks. The analysis of required simulator performances as deduced from the training task list was accomplished by creating a list of simulation areas broken into component parts. The simulation areas considered were:

- Basic flight simulation - used to describe the components of simulation required to model the basic aircraft flight systems and performance, including aircraft instrumentation and control loading.
- Motion - used to highlight the need for motion cues in the simulator.
- Visual presentation - used to describe the visual requirements related to training tasks.
- Tactics and gunnery - used to describe the rate of AH-64 weapons training in a mission trainer.
- Instructional controls - used to demonstrate the instructional participation required by either an instructor pilot or automated features.

The list which appears in Table A-1 is the result of a number of iterations to define specific simulation components which could relate to the AH-64 FWS. The iterations consisted of giving simulation area components to groups of training tasks and then revising the component list to reflect requirements of the training tasks. The final assignment of components to task groups appears in Table A-2. The task analysis proved useful in showing that a number of task groups (1 to 6 and 8) can be satisfied using a simulator with no visual system and no weapons simulation, apart from checking weapons panel switch positions. With the addition of a narrow FOV visual system, such as is currently in use on the CAE built CH-47C helicopter simulator, it would be possible to substantially increase the number of training task groups to include groups 1 to 26 excluding 13, 14, 15 and 16. The restricting factor on the other training groups is the capability of visual systems to display scene detail over a wide field of view.

The task analysis also shows the need for automated instructor facilities for the AH-64 FWS. Examination of the instructional control functions in the AH-64 tactical task in groups 27 to 37 reveals the task load imposed on the instructor and instructor facilities.

TABLE A-1. AH-64 FWS TASK ANALYSIS
SIMULATION ELEMENTS LIST

1. BASIC FLIGHT SIMULATION

| | |
|---|---|
| FLT | Flight, aerodynamic behaviour simulation, airframe handling & flying qualities. |
| D&C | Flight instruments, secondary controls and cockpit procedures, including controls of display management, instrument selection, etc. |
| ENG | Engines and power train, associated instruments and controls simulation, APU, etc. |
| SYST | Aircraft systems controls and functional simulation, including malfunctions and malfunction propagation simulation. |
| FLC | Primary flight controls, control forces and augmentation systems (SCAS) simulation |
| AUD | Audio effects and cockpit environment simulation. |
| NAV | Navigation aids, IFR systems controls and displays simulation. |
| ICOM | On-board communications simulation, intercom. |
| GCOM | General communications interface simulation, central tour, ATC, approach control. |

2. MOTION (GROUP 2)

| | |
|---|---|
| MOT | Primary motion cue generation. |
| PROP | Proprioceptive and secondary motion cues by vibration levels. |

TABLE A-1. SIMULATION ELEMENTS LIST (Continued)

3. VISUAL PRESENTATION

| | |
|---|---|
| PDV | Pilot's Direct Visual. Principal out-of-the-cockpit visual presentation specific to pilot's station. Scenario to include European, mountainous, desert, jungle, and arctic terrains. |
| GDV | Gunner's Direct Visual. Same as above, specific to Gunner/Copilot Station. |
| PNDV | Pilot's Night Direct Visual. Same as PDV, for nighttime conditions, specific to pilot's station. |
| GNDV | Gunner's Night Direct Visual. Same as above, specific to copilot/gunner station. |
| DVA | Direct Vision Augmentation devices simulation. Goggles, night, and reduced visibility aids. |
| EVA | Electronic Visual Augmentation devices simulation, PNVS, TADS FLIR presented via the helmet-mounted display system. |
| TVD | TADS Visual Display. Same as EVA except presented on the TADS display devices, copilot/gunner boot or CRT display. |
| GTA | Ground Target Arrays. Threat and friendly forces assets as visible on ground. Mostly static general scene with some moving items. |
| GAS | Ground Action Scenario. General battlefield activity, dynamic visual display as presented to the crew. |
| ATP | Airborne Target Presentation, threat or friendly, in the general visual field. |
| EXP | Exposure to threat. Direct visual display to crew representing hostile observation and action (fire), or the AAH being exposed to such activity. |

TABLE A-1. SIMULATION ELEMENTS LIST (Continued)

3. VISUAL PRESENTATION (Continued)

| | |
|---|---|
| WRV | Weapons Release. Visual effects of own weapons, including impact on target as observed by direct vision. |
| TSS | Tactical Sighting Systems simulation. TADS sighting scenario, (FLIR, TV, direct video) helmet-mounted display scenario, TADS recording equipment images, direct optical sighting scenes. |

4. TACTICS & GUNNERY

| | |
|---|---|
| TDC | Target Designation Controls. Crew procedures, ranging, etc., simulation. |
| WCS | Weapons Systems Controls. Procedures and cockpit activity simulation. |
| WRM | Weapons Release effects simulation as these affect the flight (motion) simulation. |
| WSM | Weapons Systems Malfunctions and Management, as related to the tactical task simulation and the mission scenario. |
| HIT | Hostile Influence on the AH-64 simulated battle damage to the AH-64 airframe and systems. |
| ASE | Aircraft Survival Equipment simulation. Radar warning, displays, procedures, etc., general crew interface with the AH-64 ASE. |
| TCOM | Tactical Communications Simulation. Interface with scouts, AH-64 team leader, ground forces, friendly airborne vehicles, etc. |

TABLE A-1. SIMULATION ELEMENTS LIST (Continued)

5. INSTRUCTIONAL CONTROLS

| | |
|---|---|
| MFM | Malfunction Management. Insert, increase/decrease of malfunction propagation conditions and severity as a means of controlling the task difficulty. |
| EFM | Environment of Flight Management. |
| TSM | Tactical Scenario Management. |
| CMA | Communications Management. |

TABLE A-2. AH-64 TASK ANALYSIS

GRP 1

BASIC FLT & A/C SYSTEMS - NORMAL START-UP & PREFLIGHT (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5401 | Utilize check list | D&C SYST FLC ICOM GCOM |
| | | TDC WCS |
| | | EFM CMA |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)
GRP 2

BASIC FLT & A/C SYSTEMS - NORMAL START-UP & PREFLIGHT (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5501 | Perform starting engine procedures | FLT D&C ENG SYST FLC AUD ICOM |
| 5502 | Perform engine runup | GCOM |
| 5506 | Perform fuel systems check | |
| 5512 | Perform de-icing systems check | PROP |
| RL | Perform start APU procedures | |
| 6001 | Perform aircraft shutdown procedures | |
| 6002 | Perform postflight check | |
| | | EFM CMA |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)
GRP 3

BASIC FLT & A/C SYSTEMS - NORMAL START-UP & PREFLIGHT (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5503 | Perform electrical systems check | D&C SYST FLC AUD ICOM |
| 5509 | Perform hydraulic systems check | |
| 5510 | Perform lights check | |
| 5513 | Perform ECU system check | |
| | | EFM |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 4

BASIC FLT & A/C SYSTEMS - NORMAL START-UP & PREFLIGHT (4)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5504 | Perform NAV systems check | SYST AUD NAV ICOM GCOM |
| 5507 | Perform communications check | CMA |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 5

BASIC FLT & A/C SYSTEMS - NORMAL START-UP & PREFLIGHT (5)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5508 | Perform flight controls check (5706) | FLT D&C ENG SYST FLC AUD ICOM |
| 5511 | Perform SCAS check | |
| 5514 | Perform pitot heater check | PROP |
| 5515 | Perform cockpit console check | |
| 5516 | Perform engine and flight instruments check | EFM |
| 5517 | Perform before-takeoff check | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)
GRP 6

BASIC FLT & A/C SYSTEMS - NORMAL START-UP & PREFLIGHT (6)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5601 | Perform go-no-go procedures (5810) | FLT D&C ENG SYST FLC AUD ICOM |
| 5602 | Perform engine health check | |
| 5603 | Monitor instruments | MOT PROP |
| 5702 | Perform prehover check | |
| 5704 | Perform flight instruments check (5516) | PDV |
| 5705 | Perform engine instruments check (5516) | |
| 5706 | Perform flight controls check (5508) | EFM |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 7

BASIC FLT & A/C SYSTEMS - CONTINGENCY PROCEDURES ON GROUND (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|
| 6819 | Identify engine fire during start | D&C | ENG | SYST | AUD | ICOM | GCOM |
| 6820 | Perform engine fire during start procedures | PROP | | | | | |
| 6829 | Perform hot start abort procedures | | | | | | |
| 6830 | Perform engine restart procedures | MFM | CMA | | | | |

## TABLE A-2 AH-64 TASK ANALYSIS (Continued)

GRP 8

BASIC FLT & A/C SYSTEMS - CONTINGENCIES ON GROUND (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 6810 | Perform hydraulic failure procedures | FLT D&C ENG SYST FLC AUD ICOM |
| 6811 | Perform chip detector procedures | GCOM |
| 6812 | Perform dc generator failure procedures | |
| 6813 | Perform clogged fuel filter procedures | PROP |
| 6815 | Perform ac inverter failure procedures | |
| 6832 | Perform transmission oil system malfunction procedures | MFM CMA |
| 6834 | Perform engine oil system malfunction procedures | |
| 6835 | Perform fuel boost pump failure procedures | |
| 6836 | Perform engine driven fuel pump failure procedures | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 9

BASIC FLIGHT & AIRCRAFT HANDLING - NORMAL CONDITIONS (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5701 | Interpret departure clearance | FLT | D&C | ENG | SYST | FLC | AUD | ICOM |
| 5703 | Perform hover taxi (6301) | GCOM | | | | | | |
| 5604 | Perform takeoff to hover | | | | | | | |
| 5605 | Perform takeoff from hover | MOT | PROP | | | | | |
| 5606 | Perform takeoff from ground | | | | | | | |
| 5607 | Perform max performance takeoff | PDV | GDV | | | | | |
| 5609 | Perform running takeoff | | | | | | | |
| 5610 | Perform max load takeoff | EFM | CMA | | | | | |
| 5613 | Perform takeoff abort | | | | | | | |
| 5614 | Perform climbout | | | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 10

BASIC FLIGHT & AIRCRAFT HANDLING - NORMAL CONDS. (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5703N | Perform hover taxi (6301) | FLT D&C ENG SYST FLC AUD NAV |
| 5604N | Perform takeoff to hover | ICOM GCOM |
| 5605N | Perform takeoff from hover | |
| 5606N | Perform takeoff from ground | MOT PROP |
| 5607N | Perform max performance takeoff | |
| 5609N | Perform running takeoff | PNDV GNDV DVA |
| 5610N | Perform maximum load takeoff | |
| 5613N | Perform takeoff abort | EFM CMA |
| 5614N | Perform climbout | |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 11

BASIC FLIGHT & AIRCRAFT HANDLING - NORMAL CONDS. (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5608 | Perform confined area takeoff | FLT D&C ENG SYST FLC AUD ICOM GCOM |
| 5612 | Perform takeoff from slope | MOT PROP |
| RL11 | Perform takeoff from pinnacle | PDV GDV |
| | | EFM CMA |

TABLE A-2 AH-64 TASK ANALYSIS (Continued)

GRP 12

BASIC FLIGHT & AIRCRAFT HANDLING - NORMAL CONDS. (4)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5608N | Perform confined area takeoff | FLT D&C ENG SYST FLC AUD ICOM GCOM |
| 5612N | Perform takeoff from slope | MOT PROP |
| RL11N | Perform takeoff from pinnacle | PNDV GNDV DVA EVA |
| | | EFM CMA |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 13

BASIC FLIGHT & AIRCRAFT HANDLING - NORMAL CONDS. (5)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5611 | Perform formation takeoff | FLT D&C ENG SYST FLC AUD ICOM GCOM |
| 5908 | Perform formation approach | MOT PROP |
| | | PDV GDV ATP |
| | | EFM CMA |

TABLE A-2 AH-64 TASK ANALYSIS (Continued)

GRP 14

BASIC FLIGHT & AIRCRAFT HANDLING - NORMAL CONDS. (6)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5611N<br>5908N | Perform formation takeoff at night<br>Perform formation approach at night | FLT D&C ENG SYST FLC AUD ICOM GCOM<br><br>MOT PROP<br><br>PNDV GNDV DVA EVA ATP<br><br>EFM CMA |

TABLE A-2 AH-64 TASK ANALYSIS (Continued)

GRP 15

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL VMC

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5801 | Perform normal traffic pattern (5809) | FLT | D&C | ENG | SYST | FLC | AUD | NAV |
| 5806 | Perform quick stop | ICOM | GCOM | | | | | |
| 5811 | Perform single pilot flight | | | | | | | |
| 0310 | Orient a map during flight | MOT | PROP | | | | | |
| 0311 | Navigate using dead reckoning | | | | | | | |
| 6201 | Perform mountaineous area flying | PDV | GDV | | | | | |
| 6203 | Perform tropic area (jungle) flying | | | | | | | |
| 6207 | Perform steep dive | EFM | CMA | | | | | |
| 6208 | Perform normal dive | | | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 16

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL, NIGHT VMC

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5801N | Perform normal traffic pattern (5809) | FLT D&C ENG SYST FLC AUD NAV |
| 5811N | Perform single pilot flight | ICOM |
| 0310N | Orient a map during flight | |
| 0311N | Navigate using dead reckoning | MOT PROP |
| 0312N | Perform night flying without night vision devices | PNDV GNDV DVA EVA |
| 6201N | Perform mountaineous area flying | |
| 6202N | Perform arctic (cold weather) flying | EFM CMA |
| 6203N | Perform tropic (jungle area) flying | |
| 6207N | Perform steep dive | |
| 6208N | Perform normal dive | |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 17

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL, DAY/NIGHT IMC

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5802 | Perform normal cruise | FLT | D&C | ENG | SYST | FLC | AUD | NAV |
| 5803 | Perform climbing turn | ICOM | GCOM | | | | | |
| 5804 | Perform descending turn | | | | | | | |
| 5805 | Perform acceleration/deceleration | MOT | PROP | | | | | |
| 5807 | Perform straight climb | | | | | | | |
| 5808 | Perform straight descent | EFM | CMA | | | | | |
| 5810 | Perform level-off check (5601) | | | | | | | |
| 0313 | Perform navigation using instruments, ADF, Doppler, FM Homing | | | | | | | |
| 6204 | Perform IMC flight | | | | | | | |
| 6206 | Perform high speed flight | | | | | | | |
| 6209 | Perform high density-altitude flight | | | | | | | |
| 6210 | Perform flight operations in NBC environment | | | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 18

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL COND. (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5809 | Monitor air space (5801) | FLT | D&C | ENG | SYST | FLC | AUD | NAV |
| 5901 | Perform prelanding check | ICOM | GCOM | | | | | |
| 5902 | Select type of approach | | | | | | | |
| 5903 | Perform normal approach to ground | MOT | PROP | | | | | |
| 5904 | Perform normal approach to hover | | | | | | | |
| 5905 | Perform shallow approach | PDV | GDV | | | | | |
| 5906 | Perform steep approach | | | | | | | |
| | | EFM | CMA | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 19

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL COND. (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5809N | Monitor air space (5801) | FLT D&C ENG SYST FLC AUD NAV |
| 5901N | Perform prelanding check | ICOM GCOM |
| 5902N | Select type of approach | |
| 5903N | Perform normal approach to ground | MOT PROP |
| 5904N | Perform normal approach to hover | |
| 5905N | Perform shallow approach | PNDV GNDV DVA EVA TVD |
| 5906N | Perform steep approach | |
| | | EFM CMA |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 20

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL COND. (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5909 | Perform slope landing | FLT D&C ENG SYST FLC AUD NAV |
| RL10/5608 | Perform confined area landing | ICOM GCOM |
| RL11 | Perform pinnacle landing | |
| | | MOT PROP |
| | | PNDV GNDV DVA EVA |
| | | EFM CMA |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 21

BASIC FLIGHT MANEUVERS & NAVIGATION - NORMAL COND. (4)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 5909N | Perform slope landing | FLT D&C ENG SYST FLC AUD NAV |
| RL10/5608N | Perform confined area landing | ICOM GCOM |
| RL11N | Perform pinnacle landing | |
| | | MOT PROP |
| | | PNDV GNDV DVA EVA |
| | | EFM CMA |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 22

BASIC FLIGHT MANEUVERS - CONTINGENCY CONDITIONS (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 6701 | Perform basic autorotation to touchdown | FLT D&C ENG SYST FLC AUD ICOM |
| 6702 | Perform basic autorotation terminated with power | GCOM |
| 6703 | Perform autorotation with power recovery | MOT PROP |
| 6704 | Perform hover autorotation | PDV GDV |
| 6705 | Perform low-level autorotation (flat glide) | MFM EFM CMA |
| 6706 | Perform low-level high-speed autorotation | |
| 6708 | Perform autorotation terminated with minimum ground roll | |
| 6709 | Perform forced landing | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)
GRP 23

BASIC FLIGHT MANEUVERS - CONTINGENCY CONDITIONS (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 6701N | Perform basic autorotation to touchdown | FLT D&C ENG SYST FLC AUD ICOM |
| 6702N | Perform basic autorotation terminated with power | GCOM |
| 6703N | Perform autorotation with power recovery | MOT PROP |
| 6704N | Perform hover autorotation | |
| 6705N | Perform low-level autorotation (flat glide) | PNDV GNDV DVA EVA TVD |
| 6706N | Perform low-level high-speed autorotation | |
| 6708N | Perform autorotation terminated with minimum ground roll | EFM CMA |
| 6709N | Perform forced landing | |

NOTE: This Group is to flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 24

BASIC FLIGHT MANEUVERS - CONTINGENCY CONDITIONS (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 6801 | Identify spatial disorientation | FLT D&C ENG SYST FLC AUD ICOM |
| 6809 | Analyze sluggish flight controls | GCOM |
| 6816 | Perform SCAS hardover failure procedures | MOT PROP |
| 6823 | Perform ditching procedures | |
| 6839 | Identify pitch-cone coupling | MFM EFM CMA |
| 6840 | Perform pitch-cone coupling procedures | |
| 6841 | Identify divergent roll | |
| 6842 | Perform divergent roll procedures | |
| 6843 | Identify rotor blade stall | |
| 6844 | Perform rotor blade stall procedures | |
| 6845 | Identify effects of cambered vertical fin | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 25

BASIC FLIGHT MANEUVERS & AIRCRAFT SYSTEMS - CONTINGENCIES

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 6802 | Perform engine failure procedures | FLT D&C ENG SYST FLC AUD NAV |
| 6803 | Perform short shaft failure procedures | ICOM GCOM |
| 6804 | Perform HS governor failure procedures | |
| 6805 | Perform LS governor failure procedures | MOT PROP |
| 6806 | Analyze inlet guide vane failure | |
| 6807 | Perform counter-torque failure procedures | PDV GDV |
| 6808 | Perform compressor stall/power surge procedures | MFM EFM CMA |
| 6814 | Perform engine oil bypass flight | |
| 6817 | Identify engine icing (air screen) | |
| 6818 | Perform engine icing (air screen) procedures | |
| 6821 | Perform A/C fire during flight procedures | |
| 6822 | Perform electrical fire procedures | |
| 6827 | Perform wing stores fire procedures | |
| 6831 | Identify transmission oil system malfunctions | |
| 6833 | Identify engine oil system malfunctions | |
| 6837 | Identify transient torque | |
| 6838 | Perform transient torque procedures | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 26

TACTICAL FLIGHT MANEUVERS & COMMUNICATION (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | |
|---|---|---|---|---|---|---|
| 1101 | Use CEOI Procedures (investigate) | D&C | SYST | AUD | NAV | ICOM |
| 1103 | Perform antijamming procedures | | | | | |
| 1106 | Operate speech security equipment (TSEC/KY-28) | TCOM | ASE | | | |
| 1108 | Operate aircraft radios | TSM | CMA | | | |
| 1110 | Operate FM homing devices | | | | | |
| 1111 | Operate electronic sensing equipment | | | | | |
| 2410 | Coordinate linkup of ground troops | | | | | |
| 2601 | Brief forward air controller | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 27

TACTICAL FLIGHT MANEUVERS & COMMUNICATION (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 6303/RL05 | Perform all-weather contour flight | FLT D&C ENG SYST FLC AUD NAV |
| 6304/RL04 | Perform all-weather low-level flight | ICOM GCOM |
| 6305 | Perform all-weather NOE flight | |
| 6306 | Report position (5211) | MOT PROP |
| 6308 | Determine obstacle clearances (6307) | |
| 6309 | Interpret terrain | PDV GDV GTA ATP |
| 2404 | Select landing zones | |
| 2407 | Select assembly areas | TCOM |
| 2408 | Select terrain flight routes for air elements | MFM EFM TSM CMA |
| 2409 | Perform convoy cover mission | |
| RL18 | Reconnoiter alternate attack positions before entering EENT | |
| RL27 | Fly to FARRP and assess logistics situation | |
| RL28 | Fly from FARRP to designated holding area | |
| MR05 | Update Doppler with laser sight. | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 28

TACTICAL FLIGHT MANEUVERS & COMMUNICATION (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| RL05/6303N | Perform all-weather contour flight | FLT D&C ENG SYST FLC AUD NAV |
| RL04/6304N | Perform all-weather low level flight | ICOM GCOM |
| RL52/6305N | Perform all-weather NOE flight using night goggles | MOT PROP |
| RL51/6305N | Perform all-weather NOE flight using PNVS | PNDV GNDV DVA EVA TVD GTA ATP |
| 6306N | Report position (5211) | |
| 6308N | Determine obstacle clearances | TCOM |
| 6309N | Interpret terrain | |
| 2404N | Select landing zones | MFM EFM TSM CMA |
| 2407N | Select assembly areas | |
| 2408N | Select terrain flight routes for air elements | |
| 2409N | Perform convoy cover mission | |
| RL18N | Reconnoiter alternate attack positions before entering EENT | |
| RL27N | Fly to FARRP and assess logistics situation | |
| RL28N | Fly from FARRP to designated holding area | |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 29

TACTICAL FLIGHT MANEUVERS & COMMUNICATION (4)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| RL19 | Move into attack position | FLT | D&C | ENG | SYST | FLC | AUD | NAV |
| 6301 | Perform (masked) hover in ground effect | ICOM | | | | | | |
| 6302 | Perform hover out of ground effect | MOT | PROP | | | | | |
| 6307/6312 | Perform mask/unmask | | | | | | | |
| 6310/2405 | Perform evasive maneuvers | PDV | GDV | EVA | TVD | GTA | GAS | ATP |
| 6312/6307 | Perform popup maneuvers | EXP | TSS | | | | | |
| 2402 | Prepare spot reports | | | | | | | |
| 2709/RL33 | Perform aircraft camouflage (smoke?) | TCOM | | | | | | |
| 2710 | Perform aircraft dispersal | | | | | | | |
| 2401/RL14 | Perform reconnaissance flight | EFM | TSM | CMA | | | | |
| MR00 | Perform maneuvers based on visual commands (anticollision lights, etc.) | | | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)
GRP 30

TACTICAL FLIGHT MANEUVERS & COMMUNICATION (5)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| RL19N | Move into attack position | FLT D&C ENG SYST FLC AUD NAV |
| 6301N | Perform (masked) hover in ground effect | ICOM GCOM |
| 6302N | Perform hover out of ground effect | MOT PROP |
| 6307N/6312N | Perform mask/unmask | |
| 6310N/2405N | Perform evasive maneuvers | PNDV GNDV DVA EVA TVD GTA GAS |
| 6312N/6307N | Perform popup maneuvers | ATP EXP TSS |
| 2402N | Prepare spot reports | |
| 2709N/R135N | Preform aircraft camouflage | TCOM |
| 2710N | Perform aircraft dispersal | |
| 2401N/RL14N | Perform reconnaissance flight | EFM TSM CMA |
| MR00N | Perform maneuvers based on visual commands | |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 31

TACTICS (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| RL31 | Acquire and identify stationary targets by direct vision (MR 5101) | FLT D&C ENG SYST FLC AUD NAV ICOM |
| RL38 | Use optical devices to acquire and identify stationary targets (MR 5103) | MOT PROP |
| RL37 | Use FLIR to acquire and identify stationary targets (MR 5102) | PDV GDV EVA TVD GTA GAS ATP |
| 2704 | Perform/receive target handoff | EXP |
| 2707 | Perform combined arms team operations | |
| RL44 | Acquire and identify moving targets by direct vision (MR 5107) | TDC WCS WSM TCOM |
| RL41 | Acquire and identify airborne vehicles by direct vision (MR 5107) | EFM TSM CMA |
| RLxx | Acquire and identify moving targets by other than direct vision or optics | |
| 6607 | Analyze target data | |
| 2703 | Perform techniques of movement (Moving between attack points with a minimum of exposure) | |
| MR01 | Record and analyze battlefield scenes using TADS | |
| MR02 | Follow scout to firing position | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 32

TACTICS (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| RL31N | Acquire and identify stationary targets by direct vision (MR 5101) | FLT D&C ENG SYST FLC AUD ICOM |
| RL38N | Use optical devices to acquire and identify stationary targets (MR 5103) | MOT PROP |
| RL37N | Use FLIR to acquire and identify stationary targets (MR 5102) | PNDV GNDV DVA EVA TVD GTA GAS<br>ATP EXP TSS |
| 2704N | Perform/receive target handoff | |
| 2707N | Perform combined arms team operations | TDC WCS TCOM WSM |
| RL44N | Acquire and identify moving targets by direct vision (MR 0906) | EFM TSM CMA |
| RL41N | Acquire and identify airborne vehicles by direct vision (MR 5107) | |
| RLxxN | Acquire and identify moving targets by other than direct vision or optics | |
| 6607N | Analyze target data | |
| 2703N | Perform techniques of movement (Move between attack points with a minimum of exposure) | |
| MR01N | Record and analyze battlefield scenes using TADS | |
| MR02N | Follow scout to firing position | |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 33

TACTICS (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| 2602 | Call for TAC air strike | FLT D&C ENG SYST FLC AUD ICOM |
| 2603 | Adjust TAC air strike | |
| 2604 | Call for indirect fires | MOT PROP |
| 2701 | Perform standoff fire | |
| 2702 | Perform massing of fires | PDV GDV EVA TVD GTA GAS ATP |
| RL15 | Call for artillery fire | EXP WRV TSS |
| XXxx | Adjust artillery fires | |
| RL45/MR5108 | Recognize threat weapons discharge | TCOM TDC WCS WRM WSM HIT ASE |
| RL49/MR5108 | Recognize threat weapons signature | |
| RL50 | Recognize effects of threat weapons on AH-64 systems | MFM EFM TSM CMA |
| RL47/MR5108 | Recognize signature of own weapons | |
| RL48 | Recognize the signatures of weapons of friendly forces | |
| 2605 | Perform target damage assessment | |
| MR04 | Perform AH-64 battle damage assessment | |
| RLxx | Utilize aircraft survival equipment | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 34

TACTICS (4)

| REF | TASK DESCRIPTION |
|---|---|
| 2602N | Call for TAC air strike |
| 2603N | Adjust TAC air strike |
| 2604N | Call for indirect fires |
| 2701N | Perform standoff fires |
| 2702N | Perform massing of fires |
| RL15N | Call for artillery fires |
| XXxx | Adjust artillery fires |
| RL45N | Recognize threat weapons discharge |
| RL49N | Recognize threat weapons signature |
| RL50N | Recognize the effects of threat weapons on AH-64 systems |
| RL46N | Recognize impact of threat weapons on the AH-64 |
| RL47N | Recognize signature of own weapons |
| RL48N | Recognize signatures of weapons of friendly forces |
| 2605N | Perform target damage assessment |
| RL20N/2606N | Call for target illumination |
| RL21N/2606N | Adjust target illumination |
| MR04N | Perform AH-64 battle damage assessment |
| RLxxN | Utilize aircraft survival equipment |

SIMULATION REQUIREMENTS

| | | | | | | |
|---|---|---|---|---|---|---|
| FLT | D&C | ENG | SYST | FLC | AUD | ICOM |
| MOT | PROP | | | | | |
| PNDV | GNDV | DVA | EVA | TVD | GTA | GAS |
| ATP | EXP | WRV | TSS | | | |
| TDC | WCS | WRM | WSM | HIT | ASE | TCOM |
| MFM | EFM | TSM | CMA | | | |

NOTE: This Group is to be flown at night.

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 35

GUNNERY (1)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5505 | Perform weapons systems check | FLT | D&C | ENG | SYST | FLC | AUD | ICOM |
| 6401 | Operate gun turret system | GCOM | | | | | | |
| 6404 | Operate 30-mm gun | | | | | | | |
| 6413 | Perform (armament) emergency procedures | MOT | PROP | | | | | |
| 6824 | Perform hung rocket procedures | PDV | GDV | EVA | TVD | TSS | | |
| 6826 | Perform runaway 30-mm gun procedures | | | | | | | |
| MS01 | Perform hung missile procedures | TDC | WCS | WSM | TCOM | | | |
| MR06 | Operate helmet-mounted sight | | | | | | | |
| MR07 | Slew TADS using helmet sight | MFM | EFM | TSM | CMA | | | |
| MR08 | Slew TADS using GPG controls | | | | | | | |
| MR10 | Track target using TADS | | | | | | | |
| MR12 | Operate data control panel and data entry keyboard | | | | | | | |
| MR13 | Operate CP/G armament control panel | | | | | | | |
| MR14 | Operate sight/acquisition source select panel | | | | | | | |
| MR15 | Operate Hellfire control panel | | | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)

GRP 36

GUNNERY (2)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| MS02 | Operate laser designation and ranging systems | FLT GCOM | D&C | ENG | SYST | FLC | AUD | ICOM |
| RL53 | Deliver 30-mm fire | | | | | | | |
| RL54 | Deliver 2.75-in rocket fire | MOT | PROP | | | | | |
| RL55 | Deliver Hellfire missile | | | | | | | |
| 2705 | Perform running fire | PDV | GDV | EVA | TVD | GTA | GAS | ATP |
| 2706 | Perform hover fire | EXP | WRV | TSS | | | | |
| 6601 | Engage enemy aircraft | | | | | | | |
| 6602 | Engage enemy anti-aircraft systems | TDC | WCS | WRM | WSM | HIT | ASE | TCOM |
| 6603 | Engage armored vehicles | | | | | | | |
| 6604 | Engage area targets | EFM | TSM | CMA | | | | |
| 6605 | Engage point targets | | | | | | | |
| 6606 | Engage personnel targets | | | | | | | |
| 6608 | Engage targets in remote mode (Hellfire) | | | | | | | |

TABLE A-2. AH-64 TASK ANALYSIS (Continued)
GRP 37

GUNNERY (3)

| REF | TASK DESCRIPTION | SIMULATION REQUIREMENTS |
|---|---|---|
| MS02N | Operate laser designation and ranging systems | FLT D&C ENG SYST FLC AUD ICOM GCOM |
| RL53N | Deliver 30-mm fire | |
| RL54N | Deliver 2.75-in rocket fire | MOT PROP |
| RL55N | Deliver Hellfire missile | |
| 2705N | Perform running fire | PNDV GNDV DVA EVA TVD GTA GAS |
| 2706N | Perform hover fire | ATP EXP WRV TSS |
| 6601N | Engage enemy aircraft | |
| 6602N | Engage enemy anti-aircraft systems | TDC WCS WRM WSM HIT |
| 6603N | Engage armored vehicles | |
| 6604N | Engage area targets | EFM TSM |
| 6605N | Engage point targets | EFM TSM |
| 6606N | Engage personnel targets | |
| 6608N | Engage targets in remote mode (Hellfire) | |

NOTE: This Group is to be flown at night.

AD-A064 415 CAE ELECTRONICS LTD MONTREAL (QUEBEC) F/G 5/9

AH-64 FLIGHT AND WEAPONS SIMULATOR CONCEPT FORMULATION STUDY. V--ETC(U)

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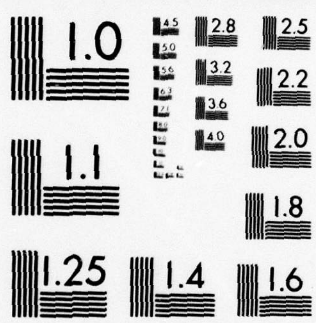


MICROCOPY RESOLUTION TEST CHART
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# APPENDIX B

## AERIAL GUNNERY TRAINING STANDARDS

## B.1 GENERAL

Aerial gunnery training standards are based on maximizing the advantages of the aerial weapons platform (speed, mobility, and firepower) and minimizing aircraft disadvantages (thin skin and limited load capability). This appendix prescribes individual, crew, and team/section standards. The standards listed represent the minimum level of proficiency required to make the attack helicopter an effective fighting weapon.

B.1.2 Individual Standards. As the basis for more advanced aerial gunnery training, individual standards must be successfully met before training on a higher level. Efficient crew coordination and flexibility in assigning crews in combat and training requires well trained individual crew members. The training standards listed in this section apply to all attack helicopter pilots, whether they will occupy a pilot position or a copilot/gunner position. Table B-1 relates these standards to specific armament subsystems. All standards apply to both day and night operations.

Attack helicopter pilots and copilot/gunners must be able to:

(1) Fly the aircraft while maintaining the established parameters of the terrain flight modes: NOE, contour, and low level.

(2) Navigate the aircraft in all flight modes and maintain accurate orientation within 100 meters.

(3) Use terrain and vegetation for cover and concealment while in terrain flight modes.

(4) Receive target handoffs and move swiftly from a holding position to an attack position.

(5) Give and receive crew fire commands to successfully engage targets while in terrain flight modes.

(6) Engage personnel and light material targets in terrain flight modes with the flexible weapons and techniques of engagement appropriate to the target and range.

(7) Engage tank and tank-like targets in terrain flight modes with missiles, using appropriate techniques of engagement.

(8) Engage personnel and light material targets in terrain flight modes with stowed weapons and techniques of engagement appropriate to the target and range.

(9) Transition from one target to another, using all weapons, all terrain flight modes, and all techniques of target engagement appropriate to varying situations.

(10) Perform pilot crew duties to achieve launch constraints, missile capture, and evasive action while a missile engagement is being completed.

(11) Identify and acquire targets common to the combat environment while operating in all terrain flight modes.

(12) Select and apply the proper flight mode and techniques of engagement for a particular type target and set of conditions.

B.1.3 Crew Standards. The standards in this section apply to all attack helicopter crews. Crew standards must be met to make the aerial weapons platform an effective fighting weapon, capable of participating as an element of a team or section. The teamwork required in meeting crew standards molds individual proficiency into efficient crew performance. Table B-1 relates these standards to specific armament subsystems. All standards apply to both day and night operations.

Attack helicopter crews must be able to:

(1) Demonstrate crew coordination in all terrain flight modes.

(2) Demonstrate crew coordination required to maintain a ground reference accurate within 100 meters during all terrain flight modes.

(3) Demonstrate crew coordination required to receive a target hand-off, acquire the target, and select the proper weapon to engage the target, using the flight mode and technique of target attack best suited to the situation.

(4) Demonstrate crew coordination required to acquire and engage targets of opportunity.

B.1.4 <u>Team Section Standards</u>. At the team/section level, standards are based on the ability to coordinate the fires of air and ground maneuver elements, to integrate supporting fires, and to mass these fires on the enemy at the decisive place and time. In achieving these standards, the integration of gunnery and tactics necessary to effective combat training and operations is stressed. Table B-1 relates these standards to specific armament subsystems. All standards apply to both day and night operations.

Attack helicopter teams/sections must be able to:

(1) Coordinate the fires of team elements to engage targets in order of danger to the team and associated combat elements.

(2) Coordinate target attacks within the team to maximize the capabilities of the attack helicopter.

(3) Coordinate target attacks within the team to provide mutual support through overwatching fires.

(4) Integrate the fires of the team with supporting ground and air fires and with the fires of other maneuver elements.

TABLE B-1

STANDARDS FOR SPECIFIC ARMAMENT SUBSYSTEMS IN RELATION TO TECHNIQUES OF TARGET ATTACK

Technique of Target Attack/Most Common Flight Mode

| ARMAMENT SUBSYSTEM | HOVERING FIRE<br>Terrain Flight Modes[1]<br>Nap-of-the-earth<br>STANDARD[2] | RUNNING FIRE<br>Terrain Flight Modes[1]<br>Contour/low-level<br>STANDARD[2] | DIVING FIRE<br>Altitude Flight Modes[1]<br>STANDARD[2] |
|---|---|---|---|
| FLEXIBLE MACHINEGUNS[3] Given 200 rounds | (a) Destroy moving and stationary point targets out to 1,000m range.[4]<br>(b) Neutralize 50m area targets out to 1,000m range.[4] | (a) Destroy moving and stationary point targets out to 1,000m range.<br>(b) Neutralize 50m area targets out to 1,500m range. | Destroy moving and stationary point targets out to 1,500m range. |
| FLEXIBLE GRENADE LAUNCHERS[3] Given 25 rounds | (a) Neutralize 100m area targets out to 1,000m range.<br>(b) Neutralize 50m area targets out to 1,500m range for M28 and 1,200m range for M5. | (a) Neutralize 100m area targets out to 1,000m range.<br>(b) Neutralize 50m area targets out to 1,500m range for M28 and 1,200m range for M5. | Neutralize 100m area targets out to 1,500m range. |

TABLE B-1 (Continued)

| | | | |
|---|---|---|---|
| STOWED MACHINEGUNS Given 200 rounds | (a) Destroy stationary point targets out to 800m range.<br>(b) Neutralize 50m area targets out to 1,000m range. | (a) Destroy stationary point targets out to 1,000m range.<br>(b) Neutralize 50m area targets out to 1,500m range. | Destroy moving and stationary point targets out to 1,500m range. |
| STOWED CANNONS Given 88 rounds | (a) Destroy stationary point targets out to 1,500m range.<br>(b) Neutralize 50m area targets out to 2,000m range. | (a) Destroy stationary point targets out to 2,000m range.<br>(b) Neutralize 50m area targets out to 2,500m range. | Destroy moving and stationary point targets out to 3,000m range. |
| ROCKETS[5] Given 4 rounds | (a) Neutralize 100m area targets out to 2,000m range.<br>(b) Neutralize 200m area targets out to 3,500m range.<br>(c) Neutralize 400m area targets out to 5,500m range. | (a) Neutralize 100m area targets out to 2,000m range.<br>(b) Neutralize 200m area targets out to 3,500m range.<br>(c) Neutralize 400m area targets out to 5,500m range. | (a) Neutralize 100m area targets out to 3,000m range.<br>(b) Neutralize 200m area targets out to 3,500m range.<br>(c) Neutralize 400m area targets out to 4,500m range. |

TABLE B-1 (Continued)

| | | | |
|---|---|---|---|
| MISSILES Given 1 round | Destroy moving and stationary point targets out to 3,000m range. | Destroy moving and stationary point targets out to 3,000m range. | Destroy moving and stationary point targets out to 3,000m range. |

Notes.

1. There are several flight techniques, such as ' popup ', which will result in running or hovering fire, depending on how the maneuver is executed. These techniques are not significant variables of armament accuracy and do not affect the standards.
2. All standards apply to both day and night operations.
3. The standards for flexible weapons are based on deflection engagements.
4. Destruction of point targets and neutralization of area targets are based on the following criteria:
   a. Destruction - hitting a point target with enough rounds of a given type of ammunition to permanently terminate its combat capability.
   b. Neutralization - covering an area target with enough rounds of a given type of ammunition to temporarily terminate the combat capability of elements in that area.

| | DESTRUCTION | NEUTRALIZATION |
|---|---|---|
| 7.62 mm | 50 rounds | 1 round per meter |
| 20 mm | 10 rounds | 1 round per 2 meters |

TABLE B-1 (Continued)

| | | |
|---|---|---|
| 40 mm | - | 1 round per 10 meters |
| 2.75-in Folding Fin Aerial Rocket | - | 1 rocket per 20 meters |
| Missiles | 1 missile | |

5. For purposes of ammunition conservation, 2.75-in Folding Fin Aerial Rocket target effect is not scored by actual target coverage in training.

# APPENDIX C

## SIMPLIFIED HELICOPTER ROLLING RESPONSE

## Helicopter Rolling Response

For the purpose of estimating the rolling response to cyclic control input of a typical helicopter, the following simplified calculation can be performed.

**Assumptions:**

The equations assume that

(1) The model is of a single-rotor helicopter.

(2) Rolling moment is due to rotor flapping only.

(3) Flapping is proportional to cyclic pitch and roll rate.

$$I_{xx} \cdot \dot{p} = L_{b_1} \cdot b_1$$

and

$$b_1 = \frac{\delta b_1}{\delta A_1} \cdot A_1 + \frac{\delta b_1}{\delta p} \cdot p$$

Therefore,

$$I_{xx} \cdot \dot{p} = L_{b_1} \cdot \frac{\delta b_1}{\delta A_1} \cdot A_1 + L_{b_1} \cdot \frac{\delta b_1}{\delta p} \cdot p$$

Therefore,

$$p = \frac{K.A_1}{1+s\tau}$$

where

$$\tau = \frac{-1}{\frac{L_{b_1}}{I_{xx}} \cdot \frac{\delta b_1}{\delta p}}$$

and

$$K = \frac{\delta b_1 / \delta A_1}{\delta b_1 / \delta p}$$

Where $I_{xx}$ is moment of inertia about x axis

$p$ is roll rate

$L_{b_1}$ is rolling moment due to lateral flapping

$b_1$ is lateral flapping angle

$A_1$ is lateral cyclic pitch

$T$ is thrust

$L_R$ is rolling moment due to rotor

$h_R$ is height of rotor above center of gravity

$W$ is aircraft weight

$\Omega$ is rotor speed

$\gamma$ is Locke number

## CH-53 Rolling Response

For the purpose of estimating the basic rolling response of the CH-53 helicopter, the following simplified moment equation has been extracted from Sikorsky Report SER 65 247, Equations of Motion, Assumptions and Description of CH-53 Helicopter.

$$L_R = 495000\ b_1 + T\ .\ b_1\ .\ h_R$$

Assume

$$T = W \simeq 35000 \text{ lb}$$

$$h_R \simeq \frac{1(256-184)}{12} = \frac{72}{12} = 6 \text{ ft}$$

Therefore,

$$\frac{\delta L_R}{\delta b_1} = L_{b_1} = 495000 + 35000 \times 6$$

$$= 705000 \text{ lb. ft /rad}$$

$$b_1 = A_1 - \frac{16}{\gamma}\ \frac{p}{\Omega o}$$

$$\gamma = \frac{1.276}{16}$$

$$\Omega o = 19.33$$

Therefore,

$$b_1 = A_1 - 0.066p$$

Therefore,

$$\frac{\delta b_1}{\delta p} = -0.066$$

$$\frac{\delta b_1}{\delta A_1} = 1$$

In the steady state,

$$\frac{\delta p}{\delta A_1} = \frac{\delta b_1 / \delta A_1}{\delta b_1 / \delta p} = \frac{1}{-0.066}$$

$$= -15 \text{ deg/sec per deg}$$

Control range is 7.5 degrees over 12 inches.

Therefore,

$$\text{Control gain} = \frac{7.5}{12} = 0.62 \text{ deg/inch}$$

and

$$\text{Roll rate} = 15 \times 0.62 = 10^{\circ}\text{/sec/inch}$$

# APPENDIX D

## SANDERS GRAPHICS 7 DISPLAY REFRESH TIMING ANALYSIS

D.1 OBJECTIVE To show that one Sanders Graphic 7 controller can support the display load of the instructor stations.

D.2 Introduction. The display image is generated by the Sanders Graphic 7 through refreshed strokewriting. For each visual image frame, the display file instructions are executed to provide the appropriate stroke movements, and the time to complete a frame must fall within certain values to avoid a flickering CRT image. The time limit is dependent on the type of phosphor used in the CRT. P31 phosphor, a high-speed phosphor providing precise line width and character quality, has a refresh rate of 60 frames per second. It may go down to 50 frames before flicker will become apparent. This allows 16.7 to 20 milliseconds in which the display file must be executed, respectively, to avoid degradation in image quality. P39 phosphor is the next choice, a medium-speed phosphor with a refresh rate of 40 frames per second, 35 before onset of flicker. This provides for 25 to 28 milliseconds of instruction execution time. This phosphor is adequate for this application if extra refresh time is required.

D.3 Analysis. The time requirements are calculated using the worst case situation, that is, when operating in an independent mode, and displaying high-density formats. It is assumed that the display of Figure 7-1 is on the control display and that Figure 7-2 is on the graphic display of both display systems. Both these formats have a higher than average amount of information to display.

Breakdowns of the instructions and execution times for sections of each display are shown in Tables D-1 and D-2. For the contour of Figure 7-2, vectors are used to approximate the continuous lines. All execution times include memory access, processing, and actual writing time.

The total time required to display the maximum amount of information required is calculated as follows:

| | | |
|---|---|---|
| . 2 high-density control displays | | 6.568 milliseconds |
| . 2 high-density graphic displays | | 5.407 milliseconds |
| | | 11.975 |
| . Plus 10% for display processor overheads | | 1.2 |
| | TOTAL | 13.175 milliseconds |

D.4 Conclusion. With a P31 phosphor, 16.7 milliseconds to 20 milliseconds is available for display file instruction execution. Using high density formats, it was shown that less than 14 milliseconds is required, therefore a single controller can accommodate the display refresh requirements of the instructor station with at least 25% spare time.

TABLE D-1 CONTROL DISPLAY TIMING

| | | | | |
|---|---|---|---|---|
| . INFORMATION COMMON TO BOTH STATIONS | | | | |
| 74 characters | @ 3.0 μsec | 222 | | |
| 8 lines | @ 7.0 μsec (avg.) | 56 | | |
| 34 position moves | @ 8.0 μsec (avg.) | 272 | | |
| | | 550 | X 1 | 550 μsec |
| . A/C CONDITIONS VOLATILE | | | | |
| 99 characters | @ 3.0 μsec | 297 | | |
| 19 position moves | @ 8.0 μsec | 152 | | |
| | | 449 | X 2 | 898 μsec |
| . PAGE TEXT | | | | |
| 364 characters | @ 3.0 μsec | 1092 | | |
| 4 lines | @ 7.0 μsec | 28 | | |
| 26 position moves | @ 8.0 μsec | 208 | | |
| 86 spaces | @ 1.0 μsec | 86 | | |
| | | 1414 | X 2 | 2828 μsec |
| . PAGE VOLATILE | | | | |
| 56 characters | @ 3.0 μsec | 168 | | |
| 21 position moves | @ 8.0 μsec | 168 | | |
| | | 336 | X 2 | 672 μsec |
| . WING STORES STATUS | | | | |
| 98 characters | @ 3.0 μsec | 294 | | |
| 21 lines | @ 1.0 μsec | 210 | | |
| 38 position moves | @ 8.0 μsec | 306 | | |
| | | 810 | X 2 | 1620 μsec |
| | | | | 6568 μsec |

TOTAL = 6.568 msec for both control displays

NOTE: Also see Figure 7-1.

TABLE D-2 GRAPHIC DISPLAY TIMING

| | | | | |
|---|---|---|---|---|
| . INFORMATION COMMON TO BOTH STATIONS | | | | |
| 5 long vectors | @ 25 μsec (avg.) | 125 | | |
| 9 vectors | @ 4 μsec | 36 | | |
| | | 161 | X 1 | 161 μsec |
| . TIME HISTORY PLOT | | | | |
| 440 short vectors | @ 2.4 μsec | 1056 | | |
| 31 characters | @ 3.0 μsec | 93 | | |
| 12 position moves | @ 8.0 μsec | 96 | | |
| | | 1245 | X 2 | 2490 μsec |
| . ENGAGEMENT SUMMARY (estimate) | | | | |
| | | 500 | X 2 | 1000 μsec |
| . CONTOUR | | | | |
| 100 short vectors | @ 2.4 μsec | 240 | | |
| 150 longer vectors | @ 3.5 μsec | 525 | | |
| 19 characters | @ 3.0 μsec | 57 | | |
| 7 position moves | @ 8.0 μsec | 56 | | |
| | | 878 | X 2 | 1756 μsec |
| | | | | 5407 μsec |

TOTAL = 5.407 msec for both graphic displays

NOTE: Also see Figure 7-2.

# APPENDIX E

## SANDERS GRAPHIC 7 SPECIFICATION

## GRAPHIC 7 TERMINAL CONTROLLER (MODEL 5710) SPECIFICATION

### GENERAL

| | |
|---|---|
| Power Source | 115 ± 10 Vac<br>47 to 63 Hz |
| Power | 300 W |
| Temperature-Storage | $0^{o}$ to $50^{o}$C |
| Temperature-Operating | $15^{o}$ to $40^{o}$C |
| Relative Humidity | 10 to 90% |
| Dimensions: Height | 10.5 in |
| Width | 19.0 in |
| Depth | 16.0 in |
| Weight | 55 lb |

### DISPLAY PROCESSOR

| | |
|---|---|
| General Purpose Microprocessor | Yes |
| Word Length | 16 bits |
| Byte Mode | 8 bits |
| Instructions | 400 plus |
| Registers | 8 |
| Hardware Stacks | Yes |
| Automatic Priority Interrupt | Yes |
| Memory | 16 bits |
| ROM | 4,096 words |
| RAM | 8,192 words |
| Expansion RAM to | 24,576 words |

### INTERFACE OPTIONS (DIGITAL)

| | |
|---|---|
| Parallel | 16 bits |
| Serial | RS-232C |

### GRAPHIC CONTROLLER

| | |
|---|---|
| Parallel Microprocessor | 16 bits |
| Display Instructions | 40 |
| Synchronized Linkage to Display Processor | Yes |
| Subroutine Stack | Yes |
| Display Registers | 13 |
| Registers (GP) | 4 |
| Refresh Rates | 60, 40, 30 Hz |

### VECTOR/POSITION GENERATOR

| | |
|---|---|
| Addressable Locations | 2048 x 2048 |
| Viewing Area | 1024 x 1024 |
| Line Texture | 4 |
| Programmable Speeds | 2 |
| Adaptive Timing | Yes |

### CHARACTER GENERATOR

| | |
|---|---|
| Type | Cursive Stroke |
| Character Set (Std) | 96 ASCII |
| User Defined (Opt) | 96 |
| Aspect Ratio | 3:2 (normal) |
| Rotation | $90^{o}$CCW |
| Sizes | 4 |
| Tabular Characters | Auto Text Spacing |

CHARACTER GENERATOR (Continued)

| | |
|---|---|
| High Speed | 2.4 μsec (typical) |
| | 3.6 μsec (with tab) |
| Programmable Speeds | 2 |
| Adaptive Timing | Yes |

OUTPUT CHANNEL

| | |
|---|---|
| Total Displays | 4 |
| X Channels | 2 |
| Y Channels | 2 |
| Z Channels | 4 |
| X, Y Channels | ±5V |
| Z Voltage | 0 to 1.5V |
| Terminations | 75Ω |
| Brightness Levels | 8 |
| Blinking (Adjustable) | 0.5 to 5.0 Hz |
| Photopen Intensifier | Yes |

## GRAPHIC 7 DISPLAY INDICATOR SPECIFICATION

| | Model 530 | Model 565 |
|---|---|---|
| Viewing Area (max.) | 12 x 16 in | 20 in circular |
| CRT | 21 in diagonal | 23 in round |
| Character Write Time | 150 nanoseconds per stroke | 150 nanoseconds per stroke |
| Positioning Time | 25 microseconds | 25 microseconds |
| Position Accuracy (% of full scale) | ±1% | ±1% |
| Position Repeatability (% of full scale) | ±0.1% | ±0.1% |
| Contrast Ratio | 4:1 | 4:1 |
| Line Width, Spot Size | 0.02 in | 0.02 in |
| Power | 275 W | 275 W |
| Approximate Size | 24 x 28 x 20 in | 59 x 66 x 46 in |
| Weight | 98 lb | 348 lb |
| Phosphor | P31 (Green); others available | |
| Recommended Refresh Rate | 60 frames per second; line locked | |
| Ambient Lighting | 40 foot-candles on horizontal work surface | |
| Deflection | Electromagnetic using Sanders patented write-through-yoke techniques | |
| Focus | Low voltage electrostatic | |
| Controls | Brightness, contrast, focus, power ON/OFF | |
| Cabling | 50 ft coaxial supplied for X, Y and Z from display generator | |

## DISPLAY INSTRUCTION SUMMARY

### PART 1. CONTROL INSTRUCTIONS

```
        15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
HALT     0  0  0  0  0  0 0 0 0 0 x x x x x x   HALT
JUMP     0  0  0  0  0  0 1 0 0 0 x x x x x x   JUMP
         I              JUMP ADDRESS            (INDIRECT ADDRESS WHEN I= 1)
JRMP     0  0  0  0  0  0 1 0 0 1 x x x x x x   JUMP RELATIVE
                        JUMP INCREMENT
JMPZ     0  0  0  0  0  0 1 0 1 0 x x x x x x   JUMP IF DØ ≠ Ø
         I              JUMP ADDRESS            (INDIRECT ADDRESS WHEN I= 1)
JPRZ     0  0  0  0  0  0 1 0 1 1 X X X X X X   JUMP REL IF DØ ≠ Ø
                        JUMP INCREMENT
JMPM     0  0  0  0  0  1 0 0 0 0 X X X X X X   JUMP AND MARK
         I              JUMP ADDRESS            (INDIRECT ADDRESS WHEN I= 1)
CALL     0  0  0  0  0  1 0 0 0 1 X X X X X X   CALL SUBROUTINE
                      SUBROUTINE ADDRESS
CALR     0  0  0  0  0  1 0 0 1 0 X X X X X X   CALL RELATIVE
                      SUBROUTINE INCREMENT
RTRN     0  0  0  0  0  1 0 0 1 1 X X X X X X   RETURN
IZPR     0  0  0  0  0  1 1 0 0 0 X X X X X X   INITIALIZE
LINK     0  0  0  0  1  0 0 0 0 0 X X X X X X   SYNCHRONIZED LINKAGE
         I              LINK ADDRESS            (INDIRECT ADDRESS WHEN I= 1)
SAVD     0  0  0  0  1  0 0 0 0 1 0 0 0 0 DR#   SAVE DISP REGISTER
RESD     0  0  0  0  1  0 0 0 1 0 0 0 0 0 DR#   RESTORE DISP REGISTER
ADDI     0  0  0  0  1  0 0 0 1 1 0 0 0 0 DR#   ADD TO DISP REGISTER IMMEDIATE
                            DATA
JMPR     0  0  0  0  1  0 1 ± JUMP AMOUNT       JUMP RELATIVE AND NOP
LDRI     0  0  0  0  1  1 0 0 0 0 DEV# REG#     LOAD REGISTER IMMEDIATE
         X  X  X  X                 DATA
LDDI     0  0  0  0  1  1 0 0 0 1 0 0 0 0 DR#   LOAD DISP REG IMMEDIATE
                            DATA
LDSP     0  0  0  0  1  1 0 0 1 0 X X X X X X   LOAD STACK POINTER
                           ADDRESS
WATE     0  0  0  0  1  1 1 0 0 0 X X X X X X   REFRESH WAIT
        15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
```

NOTE: DR# = 0 to 3

DISPLAY INSTRUCTION SUMMARY (Continued)

## PART 2. DISPLAY INSTRUCTIONS

| | 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 | |
|---|---|---|
| LDDZ | 0 0 0 1 0 11 BITS DATA | LOAD DZ (Z-AXIS REGISTER) |
| LDDP | 0 0 0 1 1 11 BITS DATA | LOAD DP (DISPLAY PARAMETER REG.) |
| LDXA | 0 0 1 0 0 ± X - COORDINATE | LOAD DX ABSOLUTE |
| LDXR | 0 0 1 0 1 ± X - INCREMENT | LOAD DX RELATIVE |
| DRXA | 0 0 1 1 0 ± X - COORDINATE | DRAW X ABSOLUTE |
| DRXR | 0 0 1 1 1 ± X - INCREMENT | DRAW X RELATIVE |
| DRYA | 0 1 0 0 0 ± Y - COORDINATE | DRAW Y ABSOLUTE |
| DRYR | 0 1 0 0 1 ± Y - INCREMENT | DRAW Y RELATIVE |
| MVXA | 0 1 0 1 0 ± X - COORDINATE | MOVE X ABSOLUTE |
| MVXR | 0 1 0 1 1 ± X - INCREMENT | MOVE X RELATIVE |
| MVYA | 0 1 1 0 0 ± Y - COORDINATE | MOVE Y ABSOLUTE |
| MVYR | 0 1 1 0 1 ± Y - INCREMENT | MOVE Y RELATIVE |
| LDKX | 0 1 1 1 0 Q3Q1 X RADIUS | LOAD CONIC X |
| DRKY | 0 1 1 1 1 Q4Q2 Y RADIUS | DRAW CONIC Y |
| DRSR | 1 0 ± 5 BITS Y 0 0 ± 5 BITS X | DRAW SHORT RELATIVE |
| MVSR | 1 0 ± 5 BITS Y 0 1 ± 5 BITS X | MOVE SHORT RELATIVE |
| PPLR | 1 1 ± 5 BITS Y 0 0 ± 5 BITS X | POINT PLOT RELATIVE |
| LDTI | 1 1 0 0 0 0 0 0 0 1 TIR | LOAD TIR (TEXT INCREMENT REGISTER) |
| TEXT | 1 2nd ASCII CHAR. 1 1st ASCII | TABULAR CHARACTERS |
| CHAR | 1 0 0 1 1 1 1 B 1 ASCII CHAR. | DRAW SINGLE CHARACTER |
| | 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 | |

## GRAPHIC 7 INSTRUCTION TIMING

| INSTRUCTION | TIME (μSEC) | INSTRUCTION | TIME (μSEC) |
|---|---|---|---|
| HALT | 0.3[1] | DRKN | $9.0 + 2(R_t)^{(3)} + 4(Q_t)^{(4)(9)}$ |
| JUMP | 2.7 | LDDZ | 2.7 (0.9 if Display Select unchanged) |
| JRMP | 2.7 | | |
| JMPZ | 3.3 (1.8 if DRØ ≠ Ø) | LDDP | 2.4 |
| JPRZ | 3.0 (1.8 if DRØ ≠ Ø) | LDXA | 0.9 |
| JMPM | 3.9 | LDXR | 0.9 |
| CALL | 3.3 | DRXA | $0.7 + V_t^{(5)(9)}$ |
| CALR | 3.6 | DRXR | $0.7 + V_t^{(5)(9)}$ |
| RTRN | 2.7 | DRYA | $0.7 + V_t^{(5)(9)}$ |
| IZPR | 1.2 | DRYR | $0.7 + V_t^{(5)(9)}$ |
| LINK | 3.0[1] | MVXA | $0.4 + P_t^{(6)(9)}$ |
| SAVD | DR0:2.4, DR1:2.7, DR2 or DR3:3.0 | MVXR | $0.4 + P_t^{(6)(9)}$ |
| RESD | DR0:3.0, DR1:3.3, DR2 or DR3:3.6 | MVYA | $0.4 + P_t^{(6)(9)}$ |
| ADDI | DR0:2.4, DR1:2.7, DR2 or DR3:3.0 | MVYR | $0.4 + P_t^{(6)(9)}$ |
| JMPR | 1.5 | DRSR | 2.4 |
| LDRI | 1.8 | MVSR | 2.4 |
| LDDI | μD0:2.4, μD1:2.7, μD2 or μD3:3.0 | PPLR | 2.1 |
| LDSP | 2.4 | LDTI | 0.9 |
| WATE | 0.3 to 0.6[2] | TEXT | $2.3 + 2\ C_t^{(8)(9)}$ |
| | | CHAR | $0.7^{(10)} + C_t^{(8)(9)}$ ($2.2 + C_t$ if blinked single character). |

NOTES:

1. Time required until display halted and interrupt process started.
2. Time required to restart after frame sync pulse.
3. $R_t = 40\ {}^{L}RAD/{}^{L}MAX$* where ${}^{L}RAD$ is the horizontal radius of the conic.
4. $Q_t = 40\ {}^{L}QUAD/{}^{L}MAX$* where ${}^{L}QUAD$ is the straight line distance from the quadrant start point to the end.
5. $V_t = 40\ {}^{L}VECT/{}^{L}MAX$* where ${}^{L}VECT$ is the length of the vector.
6. $P_t = 25\ {}^{L}POS/{}^{L}MAX$* where ${}^{L}POS$ is the length of the position move.
7. L = Length of position move or vector.
8. $C_t = 0.15 \times$ (number of strokes). For example: the A is 14 strokes.
9. Instruction time should be rounded up to the next higher 0.3 μsec increment.
10. 2.2 μsec if character is blinked.

---

*${}^{L}MAX$ = the maximum on-axis dimension of the display grid.

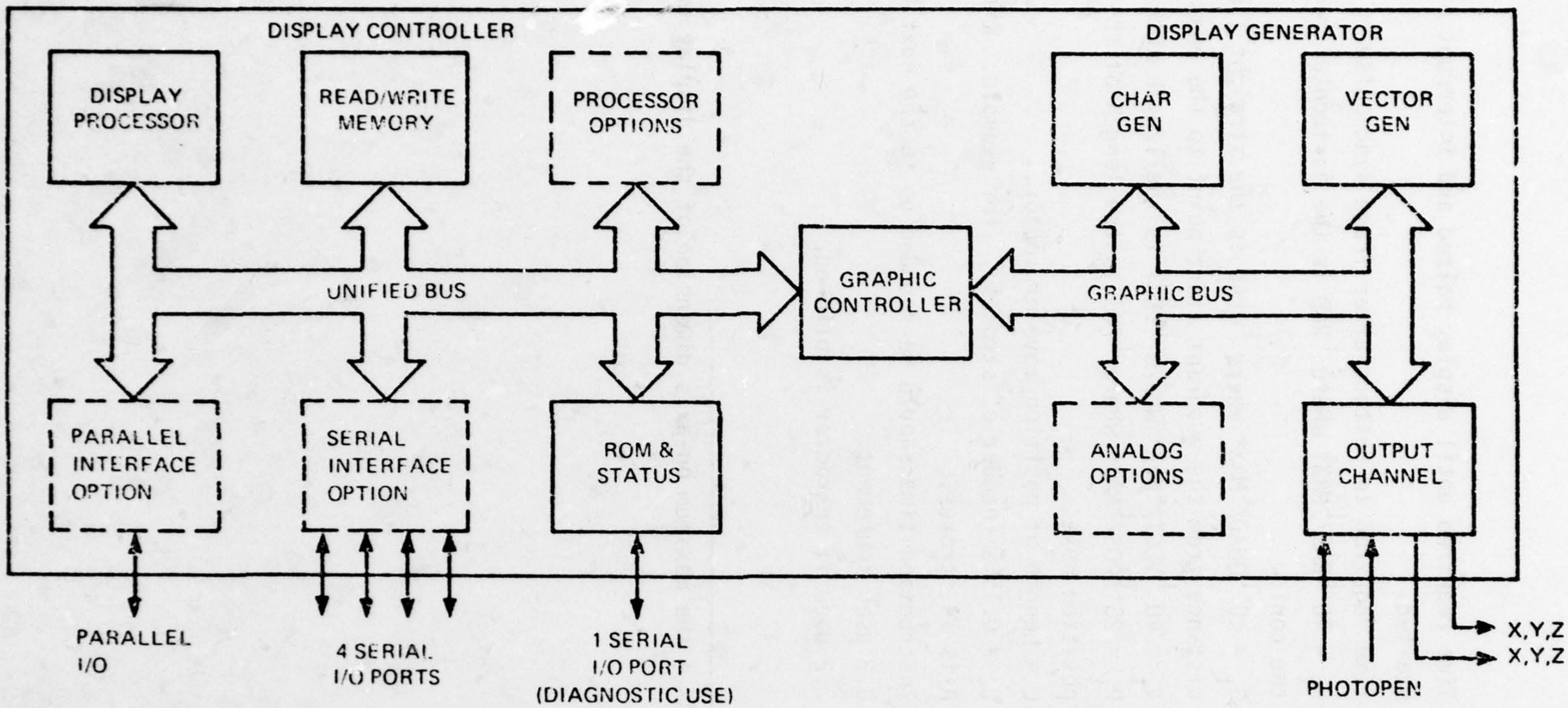



Figure E.1. GRAPHIC 7 Terminal Controller Functional Modules


Figure E.2. Basic Character Set

REGISTER FORMAT DESCRIPTIONS

(COORDINATES ARE SHOWN IN OCTAL)

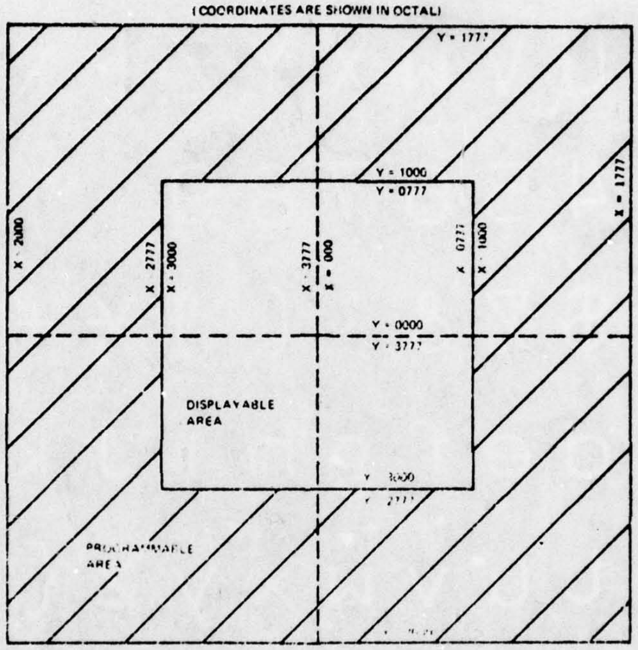



Figure E.3. Display Programmable Area.

## APPENDIX F

### DATAPATH C INTRODUCTORY DESCRIPTION

Datapath C is CAE's recently developed Simulator Interface System.

Datapath C also provides an excellent basis for the design of new data acquisition systems.

## CONTENTS



## ILLUSTRATIONS

## F. DATAPATH C

### F.1 INTRODUCTION

Datapath C provides the means by which a comprehensive range of analog and digital input and output elements may be interfaced with a control processor. The system is based on a high-speed, high-noise immunity databus, which allows several flexible configurations to be used for a complete Datapath C system.

The system is designed for maximum reliability, making extensive use of modern low-power logic families and large scale integrated circuits, simplifying the design and keeping system interconnections to a minimum. In addition, Datapath C has been designed to allow a comprehensive set of diagnostic features to be exercised on-line while the program is running. The diagnostic features enable the state of each power supply in the system to be continuously monitored and the operation of input and output modules to be verified, allowing the identification of a fault to channel or bit level in the unlikely event of a failure occurring. This reduces the mean time to repair for system hardware faults.

### F.2 SYSTEM BUILDING BLOCKS

The Datapath C family of printed circuit modules at present consists of the following cards.

F.2.1 Bus Interface Controller (BIC) Card. The BIC card controls up to 24 Datapath C input/output cards and provides the interface between the C-bus, which forms part of the Datapath C chassis backplane, and the DACBUS, which carries information to and from the computer interface unit (CIU). The BIC also contains circuitry to check the status of the chassis power supplies.

F.2.2 Digital Input (DIP) Card. The DIP card accepts up to 32 digital inputs of either contact or voltage sensing types and interfaces these inputs with the C-bus. The inputs may be programmed, via the chassis backplane, to be either contact or voltage sensing types in bytes of 8 inputs (4 bytes per DIP card). The voltage inputs are set to accept nominal +24 Vdc inputs.

F.2.3 Digital Output Transistor (DOT) Card. The DOT card accepts a 16-bit data word via the C-bus and uses this to control the state of 16 solid state outputs capable of switching +24 Vdc at up to 250 mA input current. The outputs are switched to a common return bus.

F.2.4 Digital Output Relay (DOR) Card. The DOR card accepts a 16 bit word via the C-bus and uses this to control the state of 16 isolated, single-contact relay outputs capable of switching 24Vdc or ac at up to 2A output current. Both dry contact and mercury wetted relays are available.

F.2.5 Analog Input (AIP) Card. The AIP card accepts up to 16 differential analog inputs which may be up to $\pm$ 12 Vdc (sum of differential input voltage and common mode voltage). The inputs are filtered and protected against high-voltage transients and overvoltages. The AIP card selects one of the 16 differential inputs for transmission to the ADC card via the analog A-bus.

F.2.6 Analog to Digital Converter (ADC) Card. The ADC card accepts the output of the AIP card and converts this to an 11-bit plus sign word corresponding to the bipolar, differential input voltage. Input voltage ranges of 0 to $\pm$ 1 Vdc, 0 to $\pm$ 2 Vdc, 0 to $\pm$ 5 Vdc, and 0 to $\pm$ 10 Vdc may be selected under program control. The ADC card may also be instructed to automatically compensate for any offset voltages produced by the amplifiers and analog-to-digital converters (ADC) in the system.

F.2.7 Input Output Buffer (IOB) Card. The DAC BUS from the CIU can be extended up to 1500 feet. The IOB card is used to regenerate the DACBUS, enabling an additional 1500 feet extension to be made to other Datapath C chassis.

F.2.8 Diagnostic (DGN) Card. The DGN card closes a loop between the BIC card and one of several output cards, enabling the diagnostic function to be exercised on-line. The DGN card is used in chassis containing DOT, DOR, AOP, or SOP output cards.

F.2.9 Analog Output (AOP) Cards. The AOP card accepts eight 11-bit plus sign data words from the C-bus and converts them into eight 0 to ± 10 Vdc outputs, each capable of supplying up to ± 10 mA output current. Each output is passed through an active filter and is protected against short circuits to either the ± 15 Vdc power supply rails or common.

F.2.10 Synchro Output (SOP) Cards. The SOP card accepts four 11-bit plus sign data words from the C-bus and converts them into four 0 to 11.8 Vrms signals, where the sign bit controls the phase of the output with respect to a 26 Vrms, 400-Hz reference signal. Each pair of outputs is used to drive a synchro torque receiver or control transformer; thus the SOP card drives two synchro outputs. The outputs are protected against accidental short circuits.

F.2.11 AC Input (ACI) Card. The ACI card accepts four ac inputs of either 0 to 11.8 Vrms or 0 to 26 Vrms range and converts each into an 11-bit plus sign data word which may be addressed via the C-bus. The sign of each data word indicates the phase of the corresponding ac input with respect to a 400-Hz reference signal.

F.2.12 Synchro Input (SIP) Card. Each SIP card accepts two XYZ, 0 to 11.8 Vrms synchro inputs and produces a digital word corresponding to the sine and cosine of each synchro input. Each of the sine and cosine signals may be addressed via the C-bus and processed by the CPU to obtain the tangent and thus the synchro angle. Thus four channels are addressable on the SIP card, two digitized sine signals and two digitized cosine signals.

F.2.13 Analog Reference (AIR) Card. This card plugs into an analog input chassis and produces 8 bipolar reference signals of either ± 10 Vdc or ± 5 Vdc. These reference voltages may then conveniently be used to power any potentiometers which are fed back into the analog input system.

F.3 CHASSIS CONFIGURATIONS. Physically a Datapath C chassis consists of a standard 19 inch wide card case, which accepts up to 27 printed circuit boards, each 9.2 inches X 9.2 inches, on 0.6-inch pitch. Each card has two sets of rear edge connector positions, P1 is the upper set, and P2 the lower. For an input or output card, the P1 connector provides the interface between the card and the chassis data and control bus (the C-bus) from the BIC. The P2 connector provides the input and output connections to the external system or plant.

The BIC and IOB cards have a third connector at the front of the printed circuit card, P3, which carries the differential DACBUS between chassis and the computer interface unit (CIU).

A general chassis configuration is shown in block diagram form in Figure F-1, where a BIC controls up to 24 input or output cards via the C-bus. The various types of input or output modules may be mixed within a single Datapath C chassis. In addition to up to 24 input/output cards, many chassis will contain a diagnostic (DGN) card which forms part of the system self-check facility. This is covered in a separate section dealing with the system diagnostic features.

The only cards that form an exception to this general concept are the Analog Input (AIP) and Analog-to-Digital Converter (ADC) cards which, together with a BIC card, form an analog input chassis (Figure F-2). The ADC card communicates with the BIC via the C-bus, but the communications between the AIP card, which basically select one of 16 analog inputs, and the ADC card is via the analog bus or A-bus. The A-bus carries strobes generated by the ADC card, which operate the various switches in the AIP, and carries the selected analog signal back to the ADC card for digital conversion.

The ADC, BIC, and up to 16 AIP cards form an analog input chassis. The remaining positions in the chassis may be filled by other Datapath C cards (e.g., AOP), which are connected to the BIC by the C-bus.

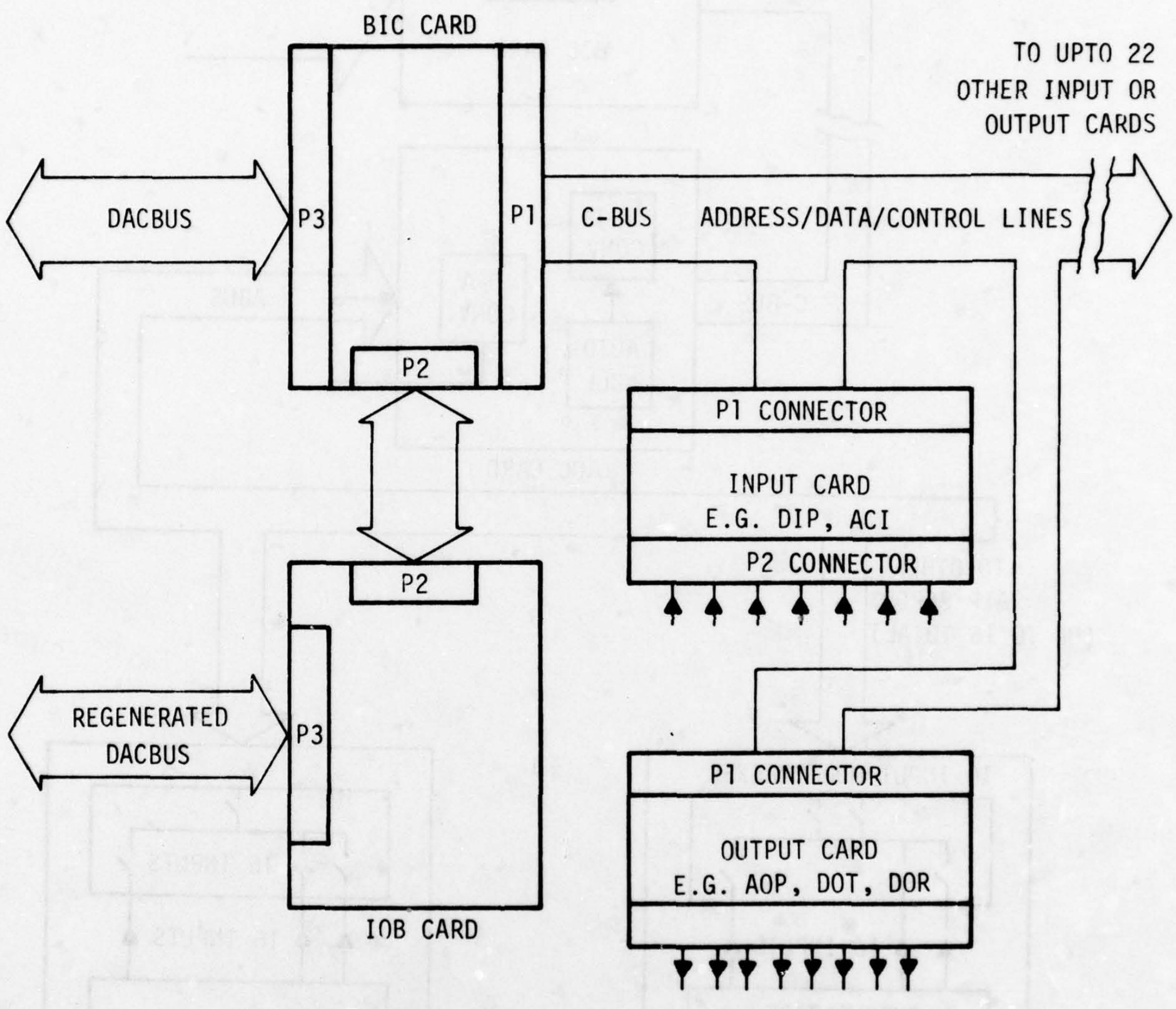



Figure F-1. Chassis Configuration and Block Diagram

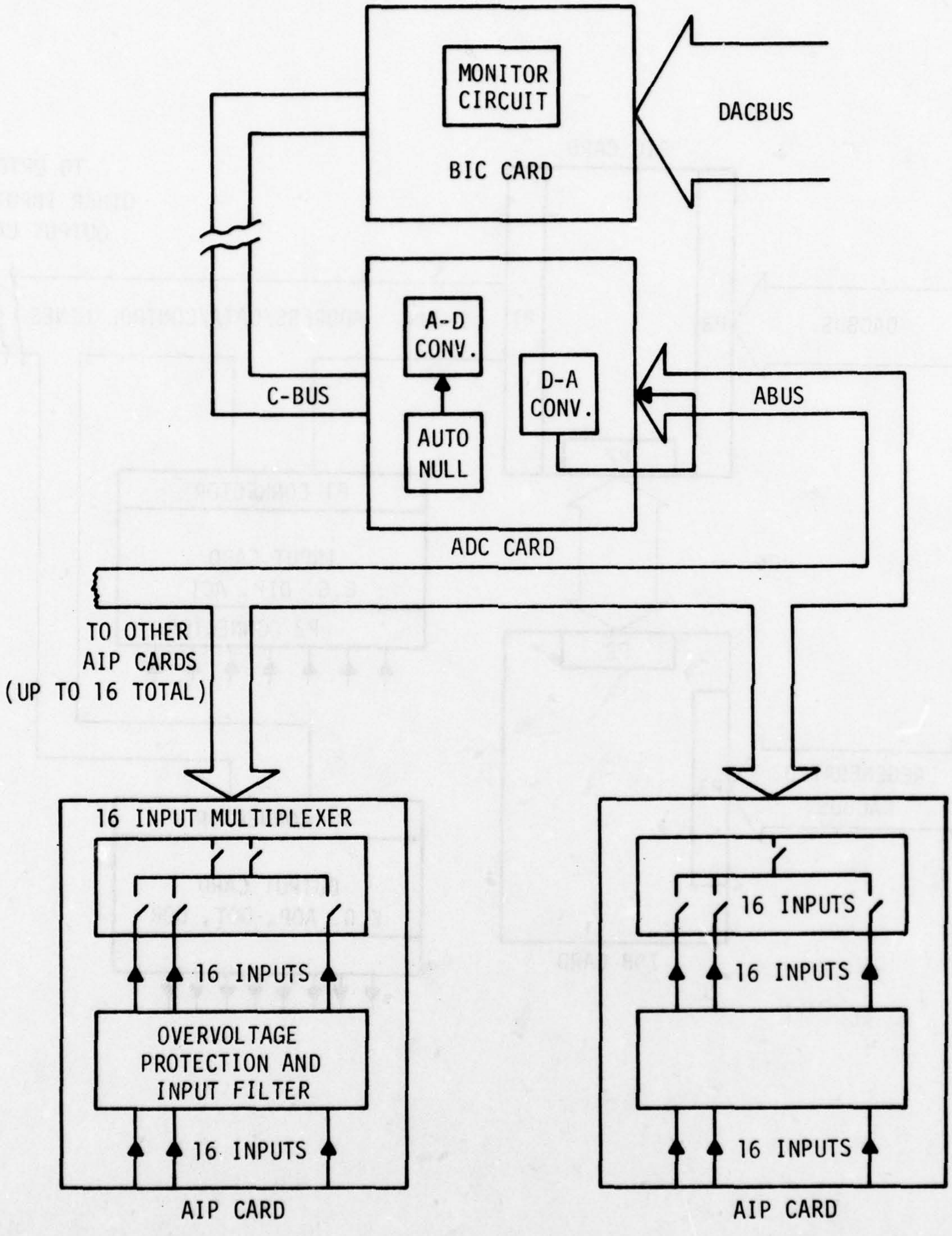



Figure F-2. Analog Input Chassis

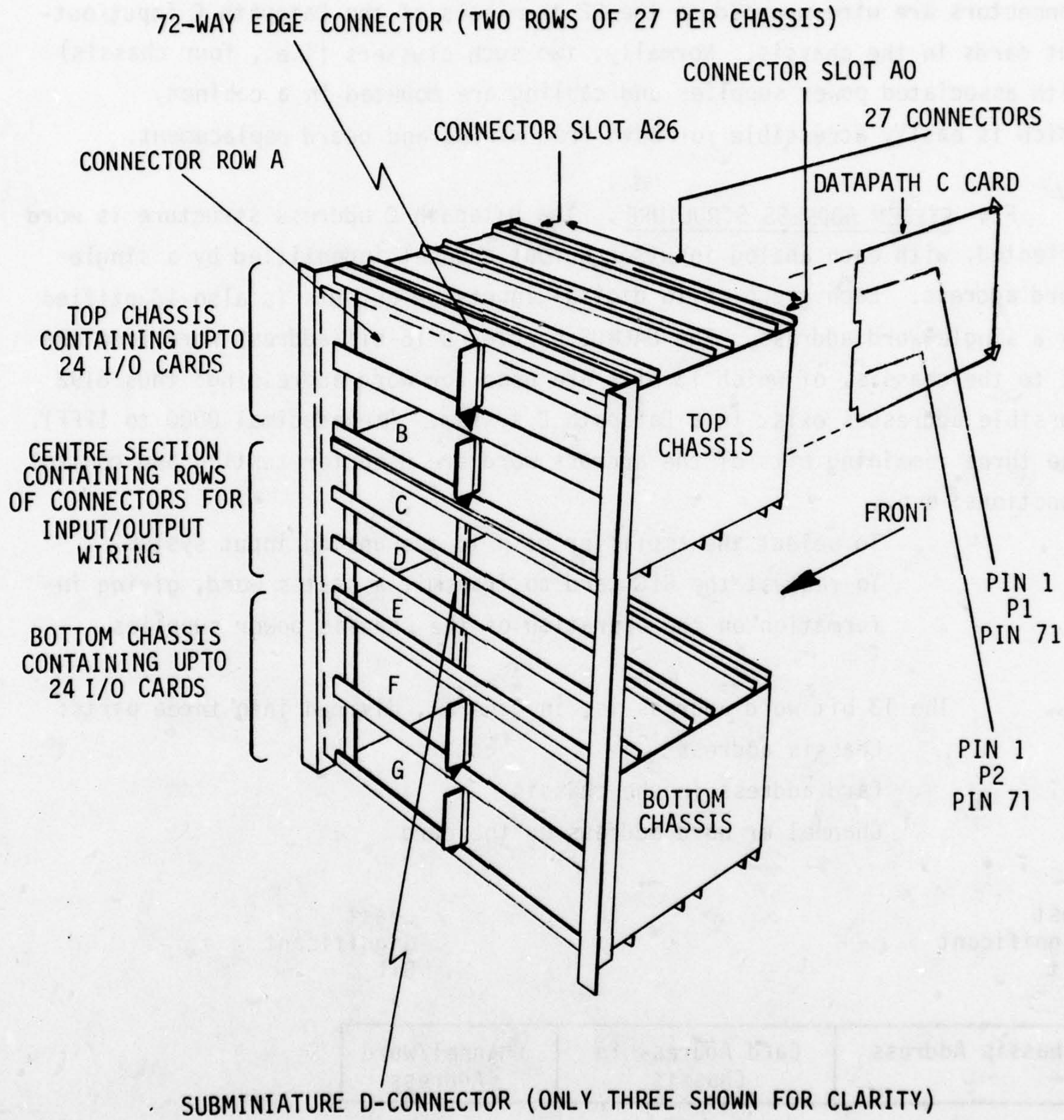



Figure F-3. Datapath C Chassis Cluster

Two Datapath C chassis are combined to form a physical assembly known as a chassis cluster (Figure F-3). The central area of the cluster between the two chassis contains three rows of subminiature D connectors, which carry the input and output connections to the system. The subminiature D connectors are wire-wrapped to the P2 terminals of the Datapath C input/output cards in the chassis. Normally, two such clusters (i.e., four chassis) with associated power supplies and cabling are mounted in a cabinet, which is easily accessible for both from wiring and board replacement.

F.4 SYSTEM ADDRESS STRUCTURE. The Datapath C address structure is word oriented, with each analog input or output channel indentified by a single-word address. Each group of 16 digital inputs or outputs is also identified by a single-word address. The DACBUS carries a 16-bit address word from the D1 to the chassis, of which 13 bits are used for word addressing: thus 8192 possible addresses exist in a Datapath C system. (hexadecimal 0000 to 1FFF). The three remaining bits of the address word are used for testing and control functions, e.g.,

- To select the amplifier gain in the analog input system.
- To request the BIC card to transmit a status word, giving information on the operation of the chassis power supplies.

The 13 bit word address is, in general, divided into three parts:

- Chassis address
- Card address in the chassis
- Channel or word address on the card

| Most Significant Bit | | Least Significant Bit |
|---|---|---|
| Chassis Address | Card Address in Chassis | Channel/Word Address |

← 13-Bit Address →

Consider for example, an analog output (AOP) card which has eight output channels. Channel 05 on this card can be addressed by setting the least significant three bits of the address word to binary 5, i.e., 101. Now assume that the card has address 17 in a chassis containing 24 AOP cards. The card address will then be binary 17, or 1001. The seven LS bits of the address word will now be

1001101 (in binary code).

The remaining 6 most significant bits constitute the chassis address. Take as an example binary 100100, then the complete word address becomes

1001001001101, which is '124D' in hexadecimal code.

Physically the card address is selected by backplane wiring of the chassis. The chassis address may be determined by one of two means, depending on customer preference, either via backplane wiring or by setting a bank of dual in-line (DIL) switches on the BIC card.

Since the number of bits required for the card and channel addresses varies, depending on the type, number, and mix of cards in a given chassis, the length of the BIC (i.e. chassis) address is variable. Its length may be determined either by backplane wiring links or via a second bank of DIL switches on the BIC card.

F.5 <u>THE DACBUS - SYSTEM DATA BUS</u>. The Datapath C DACBUS provides the only means of communication between Datapath C chassis and the CIU. Physically it consists of a flat flexible cable containing 50 conductors, which are grouped in pairs, each pair handling a differential signal. The differential signal concept enables the DACBUS to be extended up to 1500 feet and improves the noise immunity of the system greatly over levels which may be achieved with older single ended systems. When a given logical level is transmitted one of the signal lines carries a high level and the other a low level. When the logical state of the signal is changed, both of the signal lines change state. (Figure F-4). The receiver of the signal looks at the difference in the two signal levels to determine the logical state being transmitted. Any electrical noise tends to affect both lines of a signal pair in similar fashion, leaving the difference signal unchanged.

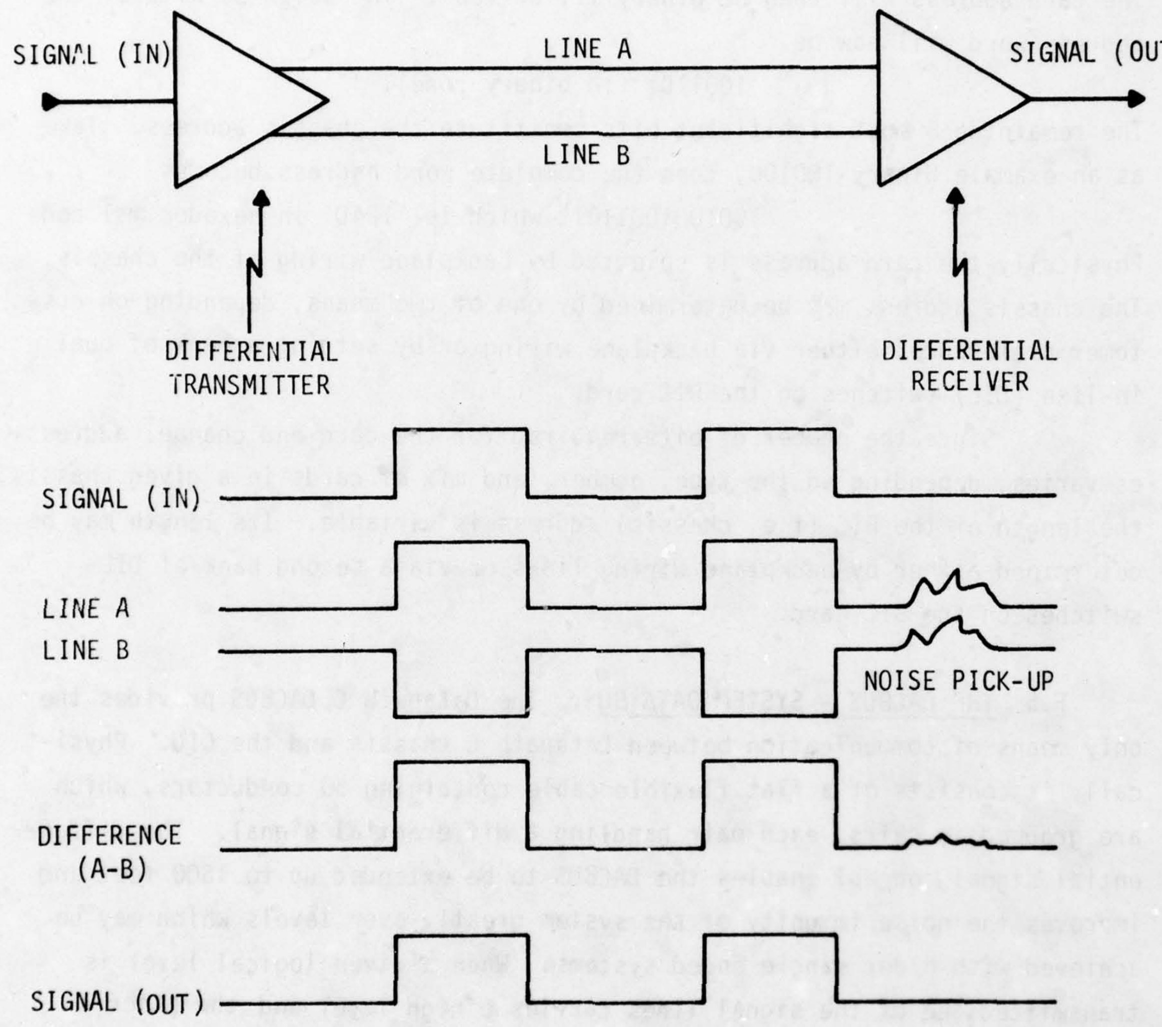



Figure F-4. Differential Signal Concept

The signal pairs in the Datapath C DACBUS are identified as follows:

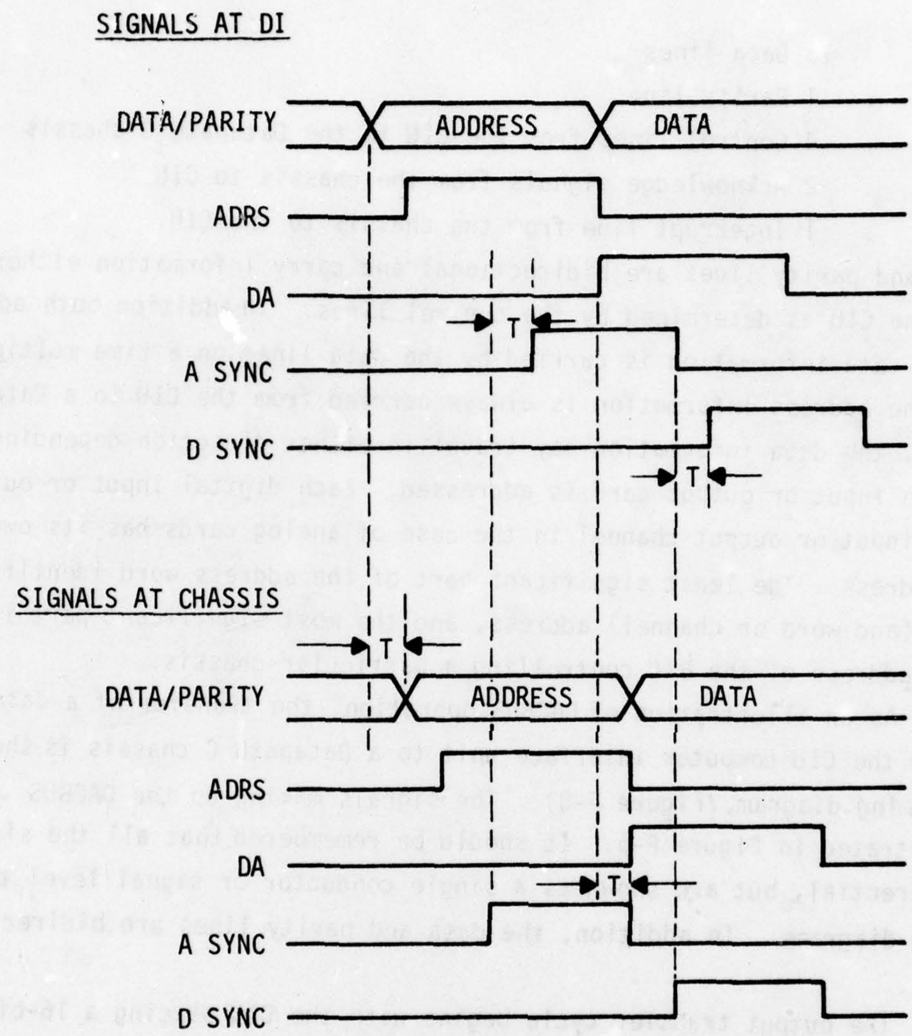
. 16 Data lines
. 1 Parity line
. 4 Control lines from the CIU to the Datapath C chassis
. 2 Acknowledge signals from the chassis to CIU
. 1 Interrupt line from the chassis to the CIU

The data and parity lines are bidirectional and carry information either to or from the CIU as determined by the control lines. In addition both address and data information is carried by the data lines on a time multiplexed basis. The address information is always carried from the CIU to a Datapath C chassis, the data information may travel in either direction depending upon whether an input or output card is addressed. Each digital input or output word, or input or output channel in the case of analog cards has its own unique address. The least significant part of the address word identifies the card (and word or channel) address, and the most significant part identifies the address of the BIC controlling a particular chassis.

As an illustration of DACBUS operation, the transfer of a data word from the CIU computer interface unit to a Datapath C chassis is shown in the timing diagram,(Figure F-5). The signals making up the DACBUS are illustrated in Figure F-6. It should be remembered that all the signals are differential, but are shown as a single conductor or signal level to simplify the diagrams. In addition, the data and parity lines are bidirectional.

The output transfer cycle begins with the CIU placing a 16-bit address word on the data lines together with the corresponding parity bit. The BIC card in each chassis checks the parity of the address and checks the address as programmed via the DIL switches or backplane wiring. If parity is good, the BIC whose address corresponds to the one on the bus responds to the Address Control Strobe (ADRS) sent from the CIU by sending the Address Sync (ASYNC) signal back to the CIU. ASYNC is also dependent on the selected card within the chassis responding to the card address section of the address word.

(OUTPUT TRANSFER CYCLE)




NOTES: DACBUS SIGNALS ARE DIFFERENTIAL. ONLY THE POSITIVE TRUE SIGNAL OF THE PAIR IS SHOWN BY THE TIMING DIAGRAM.

T IS THE DELAY DEPENDENT ON THE LENGTH OF THE DACBUS.

Figure F-5. Data Transfer from CIU to a Chassis (Output Transfer Cycle)

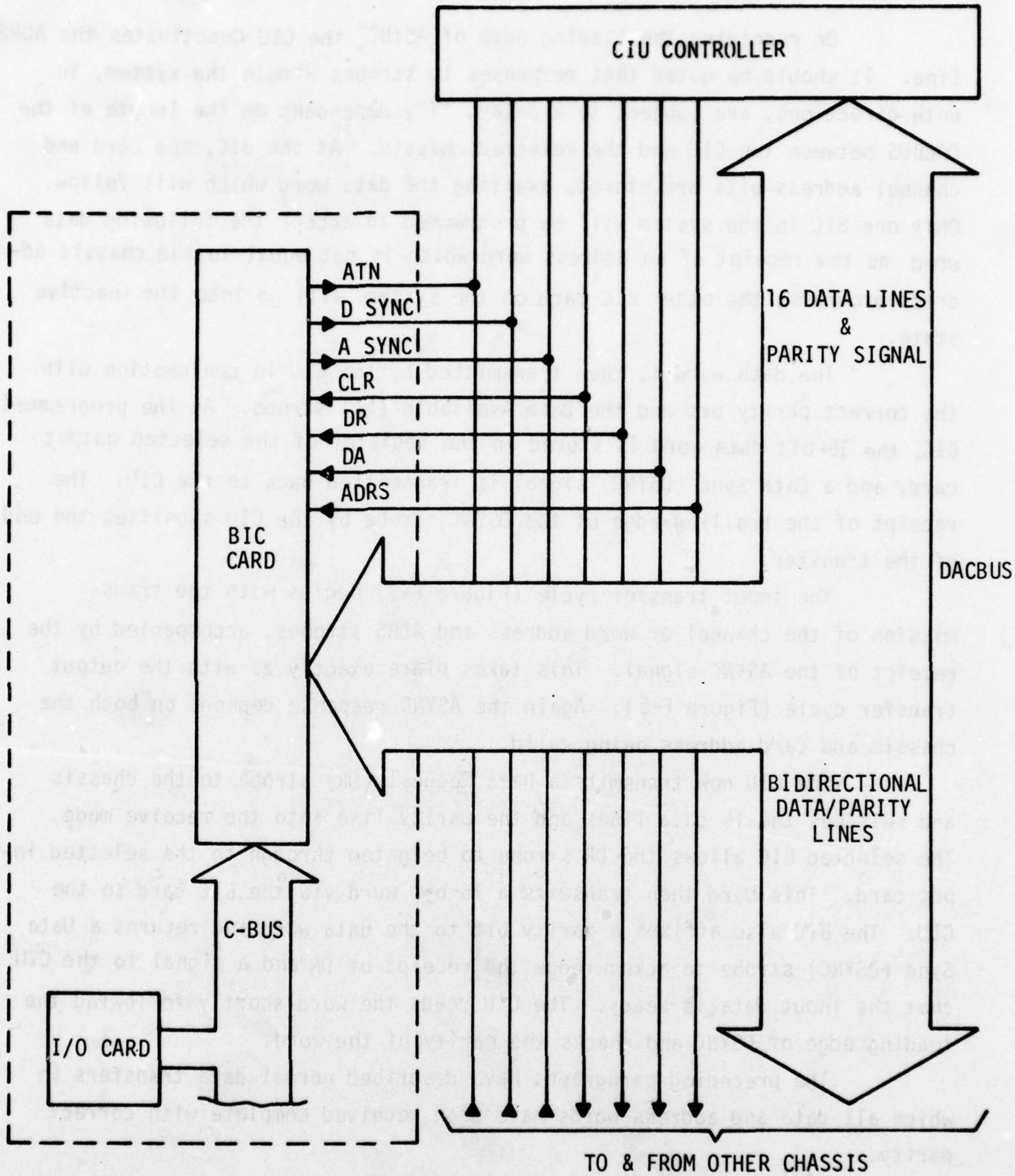



Figure F-6. DACBUS Signals

On receiving the leading edge of ASYNC, the CIU deactivates the ADRS line. It should be noted that responses to strobes within the system, in both directions, are subject to a delay, 'T', dependent on the length of the DACBUS between the CIU and the selected chassis. At the BIC, the card and channel address bits are stored, awaiting the data word which will follow. Only one BIC in the system will be programmed to accept the following data word as the receipt of an address word which is not equal to the chassis address programs, the other BIC card on the system will go into the inactive state.

The data word is then transmitted by the CIU in conjunction with the correct parity bit and the Data Available (DA) strobe. At the programmed BIC, the 16-bit data word is stored in the register of the selected output card, and a Data Sync (DSYNC) signal is transmitted back to the CIU. The receipt of the trailing edge of the DSYNC strobe by the CIU signifies the end of the transfer.

The input transfer cycle (Figure F-7) begins with the transmission of the channel or word address and ADRS strobes, accompanied by the receipt of the ASYNC signal. This takes place exactly as with the output transfer cycle (Figure F-5). Again the ASYNC response depends on both the chassis and card address being valid.

The CIU now transmits a Data Request (DR) strobe to the chassis and switches the 16 data lines and the parity line into the receive mode. The selected BIC allows the DR strobe to be gated through to the selected input card. This card then transmits a 16-bit word via the BIC card to the CIU. The BIC also affixes a parity bit to the data word and returns a Data Sync (DSYNC) strobe to acknowledge the receipt of DR and a signal to the CIU that the input data is ready. The CIU reads the word shortly following the leading edge of DSYNC and checks the parity of the word.

The preceding paragraphs have described normal data transfers in which all data and address words have been received complete with correct parity.

In the event of either the DACBUS, a BIC card, or an I/O card becoming faulty, a different sequence of responses results, enabling many system faults to be accurately identified. These are itemized in the section dealing with system diagnostic procedures.

(INPUT TRANSFER CYCLES)

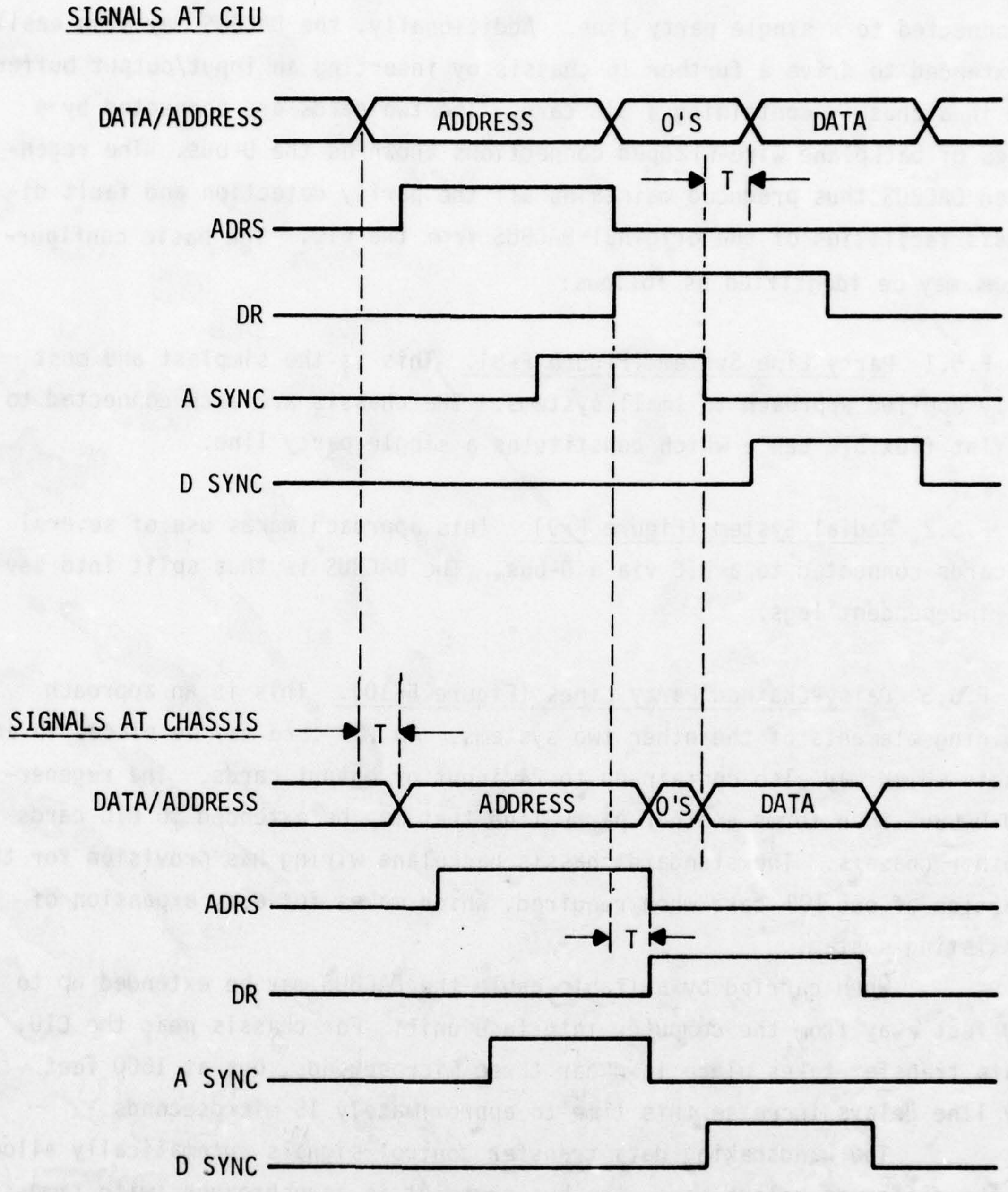



Figure F-7. Data Transfer from a Chassis to CIU
(Input Transfer Cycle)

F.6 SYSTEM CONFIGURATIONS. The bidirectional DACBUS allows a Datapath C system to be used in several configurations. Normally up to 16 chassis may be connected to a single party line. Additionally, the DACBUS may also easily be extended to drive a further 16 chassis by inserting an input/output buffer card in a chassis containing a BIC card. The two cards are connected by a series of backplane wire-wrapped connections known as the D-bus. The regenerated DACBUS thus produced maintains all the parity detection and fault diagnosis facilities of the original DACBUS from the CIU. The basic configurations may be identified as follows:

F.6.1 Party Line System (Figure F-8). This is the simplest and most easily applied approach to small systems. The chassis are each connected to the flat flexible cable which constitutes a single party line.

F.6.2 Radial System (Figure F-9). This approach makes use of several IOB cards connected to a BIC via a D-bus. The DACBUS is thus split into several independent legs.

F.6.3 Daisy-Chained Party Lines (Figure F-10). This is an approach combining elements of the other two systems. An IOB card may be placed in any chassis which may also contain up to 24 input or output cards. The regenerated DACBUS then forms another party line that may be extended to BIC cards on other chassis. The standard chassis backplane wiring has provision for the insertion of one IOB card when required, which makes for easy expansion of an existing system.

When carried by suitable cable the DACBUS may be extended up to 1500 feet away from the computer interface unit. For chassis near the CIU, a data transfer takes place in under three microseconds, but at 1500 feet away line delays increase this time to approximately 15 microseconds.

The handshaking data transfer control signals automatically allow for the different delays since the bus protocol is asynchronous (with timeout override).

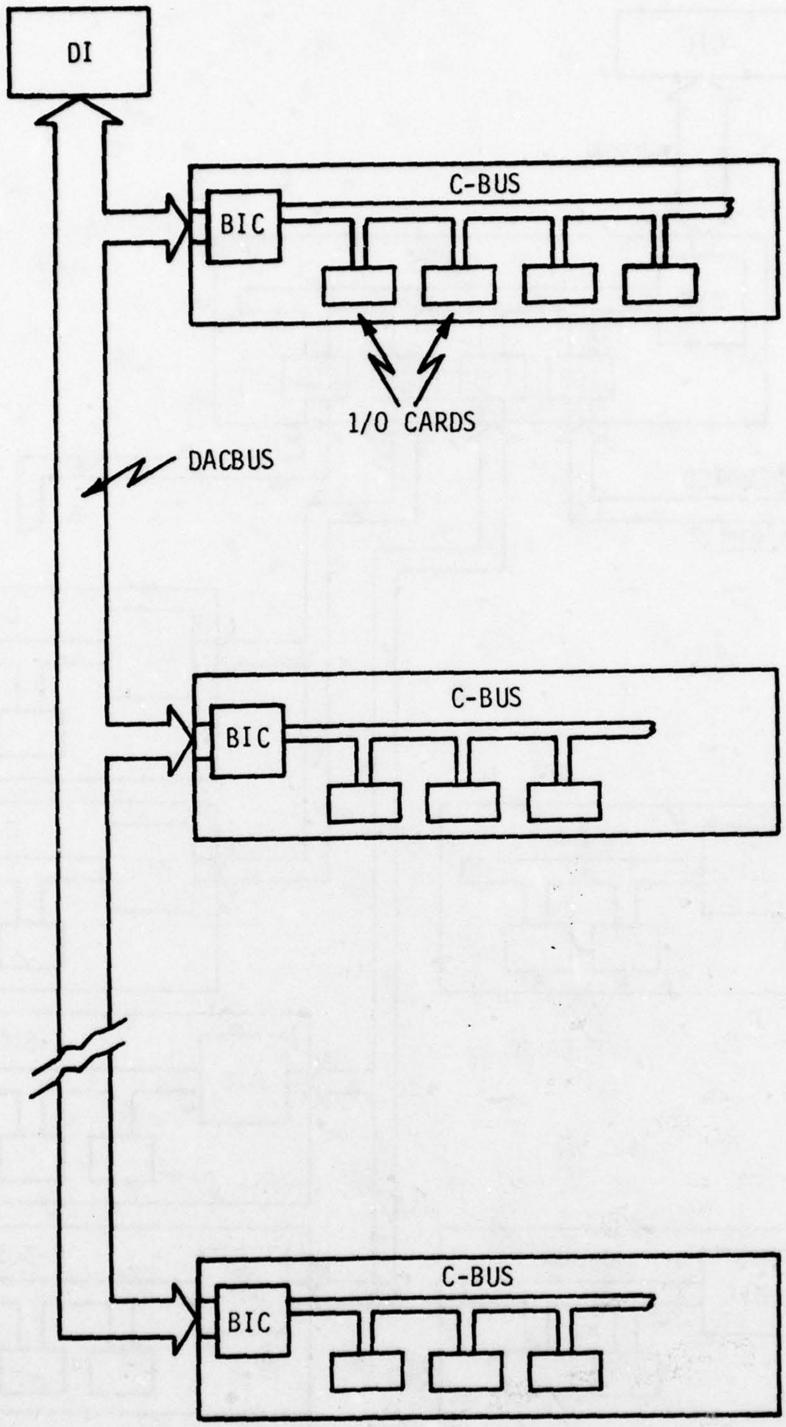



Figure F-8. Party Line System

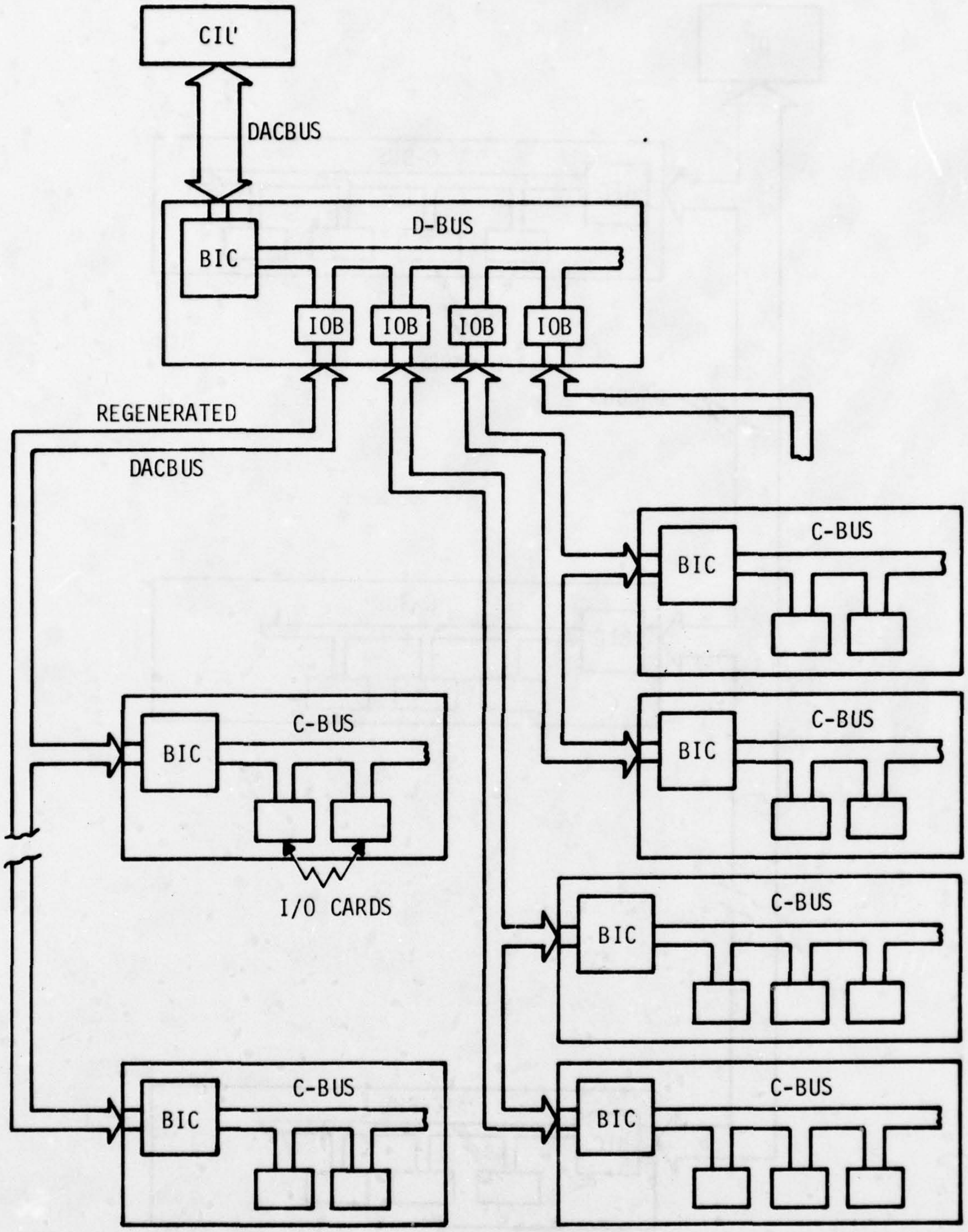



Figure F-9. Radial System

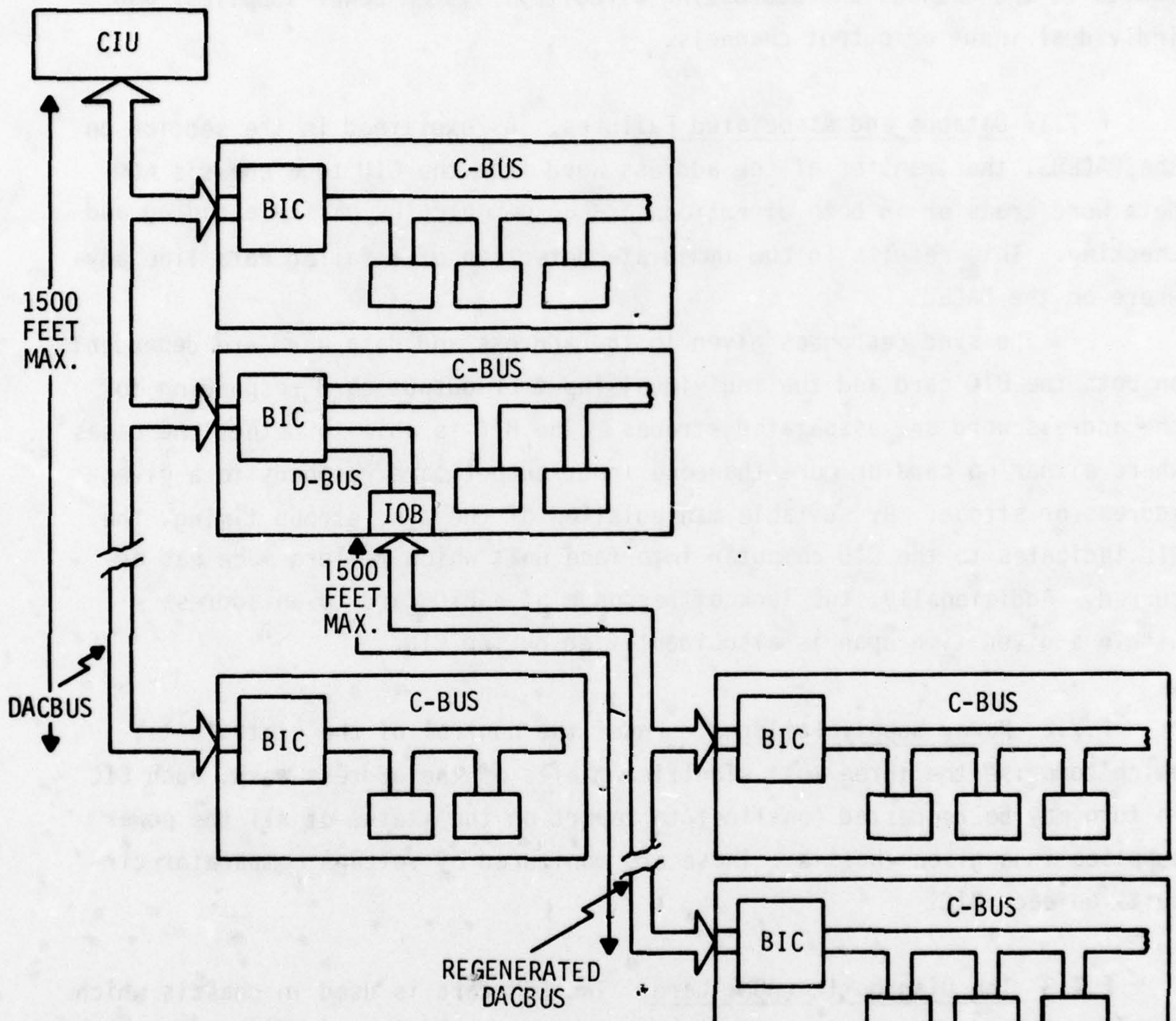



Figure F-10. Daisy Chained Party Line System

F.7 DIAGNOSTIC FEATURES The Datapath C system was designed to incorporate a comprehensive set of diagnostic features which enable a wide range of system failures to be identified by the on-line program. These include faults in the databus and addressing circuitry, system power supplies, and individual input or output channels.

F.7.1 Databus and Associated Failures. As explained in the section on the DACBUS, the transfer of the address word from the CIU to a chassis and data word transfer in both directions are accompanied by parity encoding and checking. This results in the immediate detection of a failed data line anywhere on the DACBUS.

The sync responses given to the address and data word are dependent on both the BIC card and the individual input or output card responding to the address word and associated strobes. The BIC is able to detect the cases where either no card or more than one input/output card responds to a given address or strobe. By suitable manipulation of the sync strobe timing, the BIC indicates to the CIU computer interface unit which failure mode has occurred. Additionally, the lack of response of a BIC card to an address within a given time span is also identified by the CIU.

F.7.2 Power Supply Failures. Under the control of the status bits, which comprise the three most significant bits of the address word, each BIC in turn may be requested (on-line) to report on the status of all the power supplies in a given chassis. These are monitored by voltage comparator circuits on each BIC.

F.7.3 The Diagnostic (DGN) Card. The DGN card is used in chassis which contain either analog output (AOP), synchro output (SOP), or digital output (DOT or DOR) cards. The DGN card is plugged into a vacant slot on the C-bus. The various connections between the DGN card and the AOP, SOP, DOT, and DOR cards physically form part of the backplane wiring bus which constitutes the C-bus. The various types of cards which the DGN card checks may be intermingled within the chassis.

A block diagram of the DGN card is shown in Figure F-11, which illustrates the various functions performed by the card. These may be summarized as follows:

(a) The DGN card converts an analog signal received from an AOP card into digital form, using an analog-to-digital converter module, and places the converted value on the C-bus.

(b) An ac signal from an SOP card is sampled at an appropriate time, with respect to a reference signal, using a sample and hold module. From this the rms value and phase of the signal can be detected and digitized for transmission via the C-bus.

(c) The DGN card can convert a train of serial pulses received from a DOT or DOR card (under the control of a clock on the DGN card) into a parallel data word. This word may then be placed on the C-bus.

A description of the protocol used to initiate these three diagnostic functions follows.

F.7.4 Analog Output Diagnostics (Figure F-12). The analog output card (AOP) contains eight data latches, each associated with its own digital-to-analog converter (DAC) module and output buffer. A latch is updated via a data transfer through the BIC, in which the card and channel address is followed by the updated data word and the Data Available (DA) strobe. If, however, a transfer is initiated in which the correct channel address is followed by a Data Request (DR) strobe the AOP card selects the appropriate output channel via an eight-channel multiplexer for connection to an analog signal bus which runs along the chassis backplane to the DGN card. A digital control party line, AO, is also set by the AOP card, informing the DGN card that an analog output diagnostic check has been initiated. The DGN card then converts the selected channel to digital form, the word being transmitted back to the CIU via the BIC. This data word is compared with the one used by the on-line program to last update the channel to check that the data words agree within a predetermined tolerance. In the event that they do not compare favourably, that channel on a particular AOP card has been identified as being faulty, and an appropriate printout may be initiated.

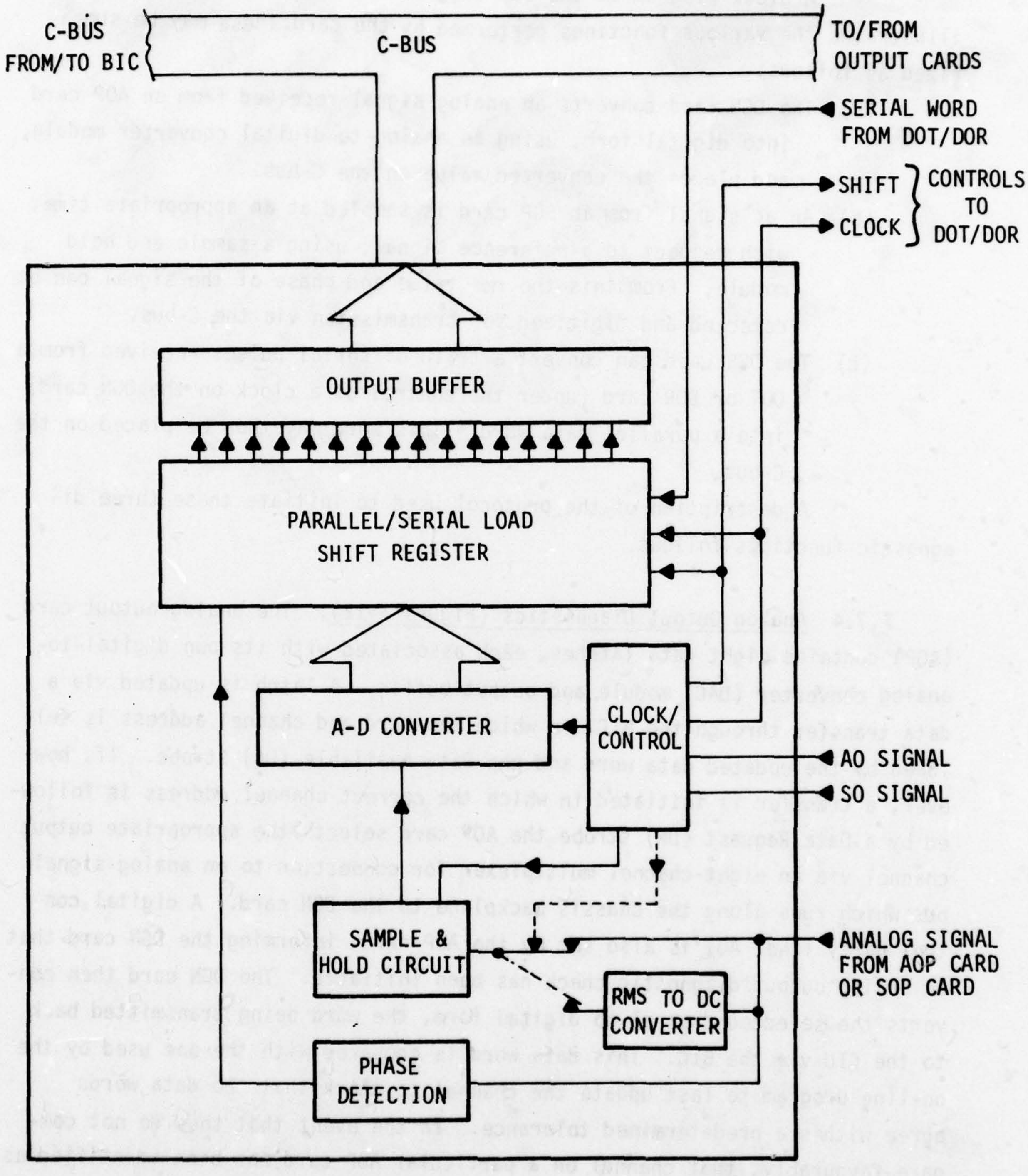



Figure F-11. Diagnostic Card Block Diagram

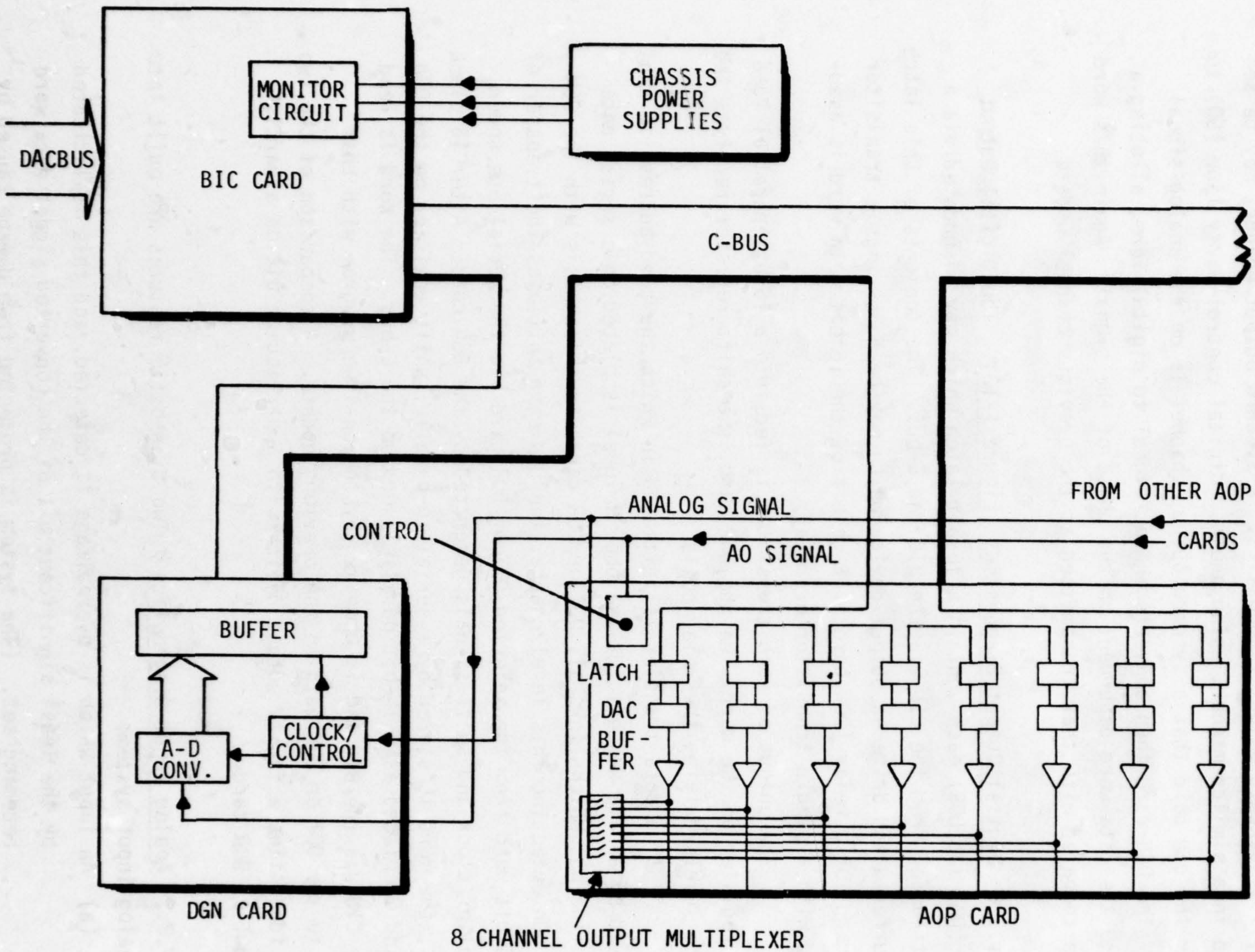


Figure F-12. Analog Output Diagnostic Loop Block Diagram

F.7.5 Synchro Output Diagnostics. A synchro output channel may be selected in a similar manner, using another digital control party line (SO) to inform the DGN card that a synchro output channel is on the analog signal line. The DGN card then converts the ac signal to digital form, alloting a sign to the data word dependent on the phase of the signal. Again this word may be compared with that transmitted at the previous channel update.

F.7.6 Digital Output Diagnostics (Figure F-13). The Digital Output Cards (DOT and DOR) each contain a 16-bit latch which may be updated via a data transfer from the CIU via the BIC and C-bus. The contents of this latch are buffered and drive an output device which may be a Darlington tranisitor (DOT card) or a relay (DOR card). Each bit of the 16-bit data word is associated with a single transistor or relay.

The output of each transistor is fed into a 16-bit parallel load shift register on the card. On the DOR card, the shift register receives the voltage levels driving the relay coils.

If a data transfer is initiated in which the card address is sent followed by a Data Request (DR) strobe, a level is placed on a serial data party line bus which links all DOT or DOR cards in the chassis with the DGN card. On detecting this level change, the DGN card initiates the transfer of the 16-bit word from the selected DOT or DOR card via the serial bus under control of clock and shift signals generated by the DGN card. After 16 clock cycles, the word is stored by a serial-to-parallel shift register on the DGN card and is placed as a 16-bit parallel word on the C-bus. The word is read by the CIU via the BIC and is compared by the on-line program with that given to the DOT or DOR card on the previous update. A comparison of the two words identifies a faulty output device with a particular bit on a particular DOT or DOR card.

F.7.7 Analog Input Diagnostics. Two diagnostic features are built into the analog input system:

(a) An input which is overvoltage is detected, and this is indicated by the least significant bit of the converted signal data word becoming set. (The system is protected from damage caused by continuous overvoltages of up to 240 Vac.)

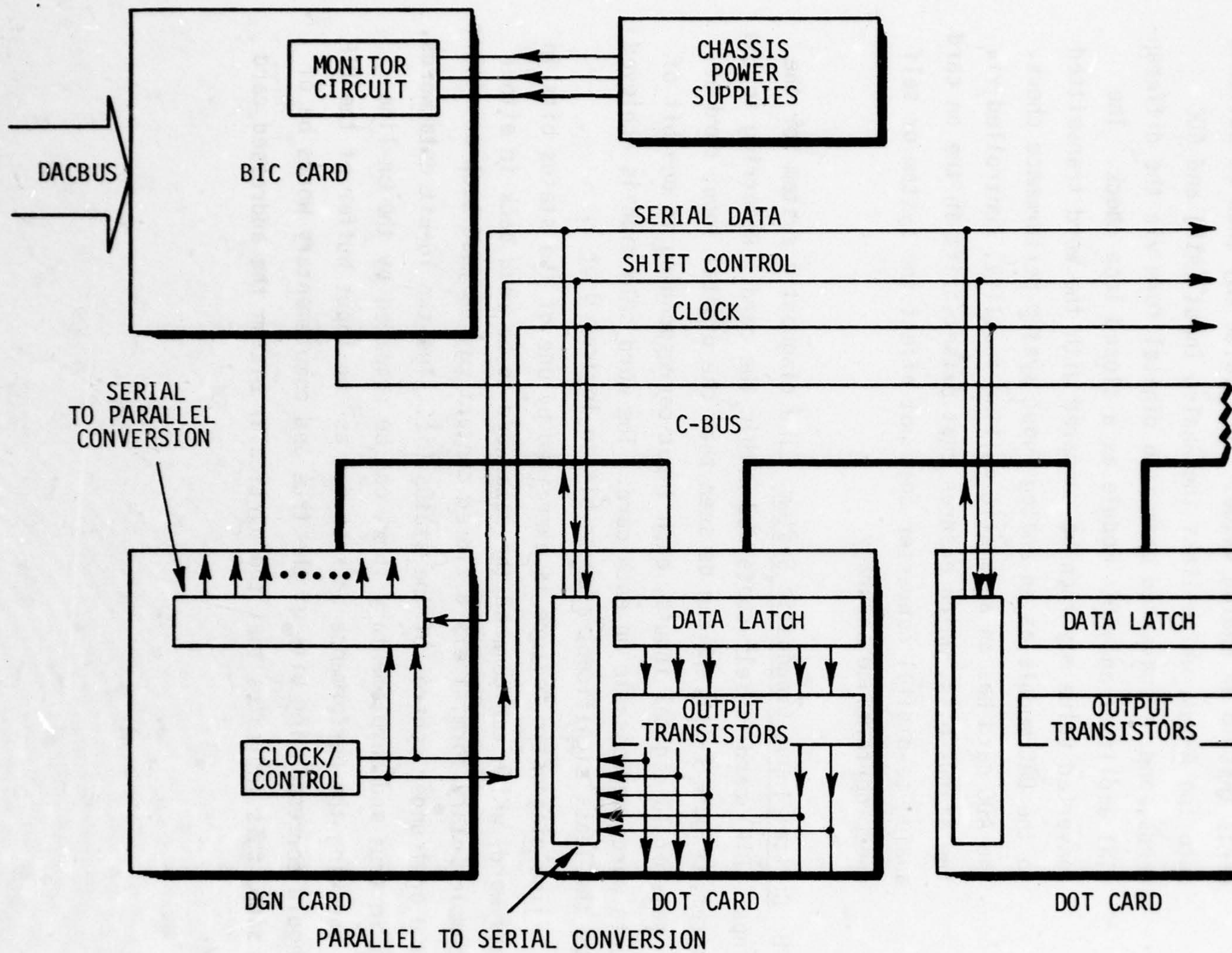



Figure F-13. Digital Output Diagnostic Loop Block Diagram

(b) When one of the address word status bits is set, a data word may then be transmitted to a DAC module on the ADC card, which converts this to an analog value. This value may then be switched onto the A-bus, which links the Analog Input (AIP) and ADC cards, and is converted back into digital form via the differential amplifier and ADC module as a closed loop check. The converted value may then be compared with the word transmitted to the DAC module as an analog input system performance check. The ADC card has an automatic nulling facility, controlled via the status bits, which ensures that offset drift in the on card analog-to-digital converter does not affect the system or self check performance accuracy.

F.7.8 Digital Input Diagnostic System. The diagnostic system for the Digital Input (DIP) card is self-contained within the card. Referring to the block diagram, (Figure F-14), it can be seen that the digital input card accepts two sets of 16 digital inputs, each input corresponding to one bit of the two data words addressable on each card. The word selection is achieved by setting the least significant address bit to logical 0 or 1.

The diagnostic feature is exercised by one of the status bits in the address word, which can command the data word to be read back in either true or complementary form, i.e., a closed contact may be read back as either a logical 0 or 1 under control of the status bit. The two 16-bit data words, read back in true and complementary form, can be compared by the on-line program, checking the performance back as far as the input buffer of the DIP card. Should corresponding bits of the true and complementary words be of the same sign, this indicates that the particular bit on the addressed card is faulty.

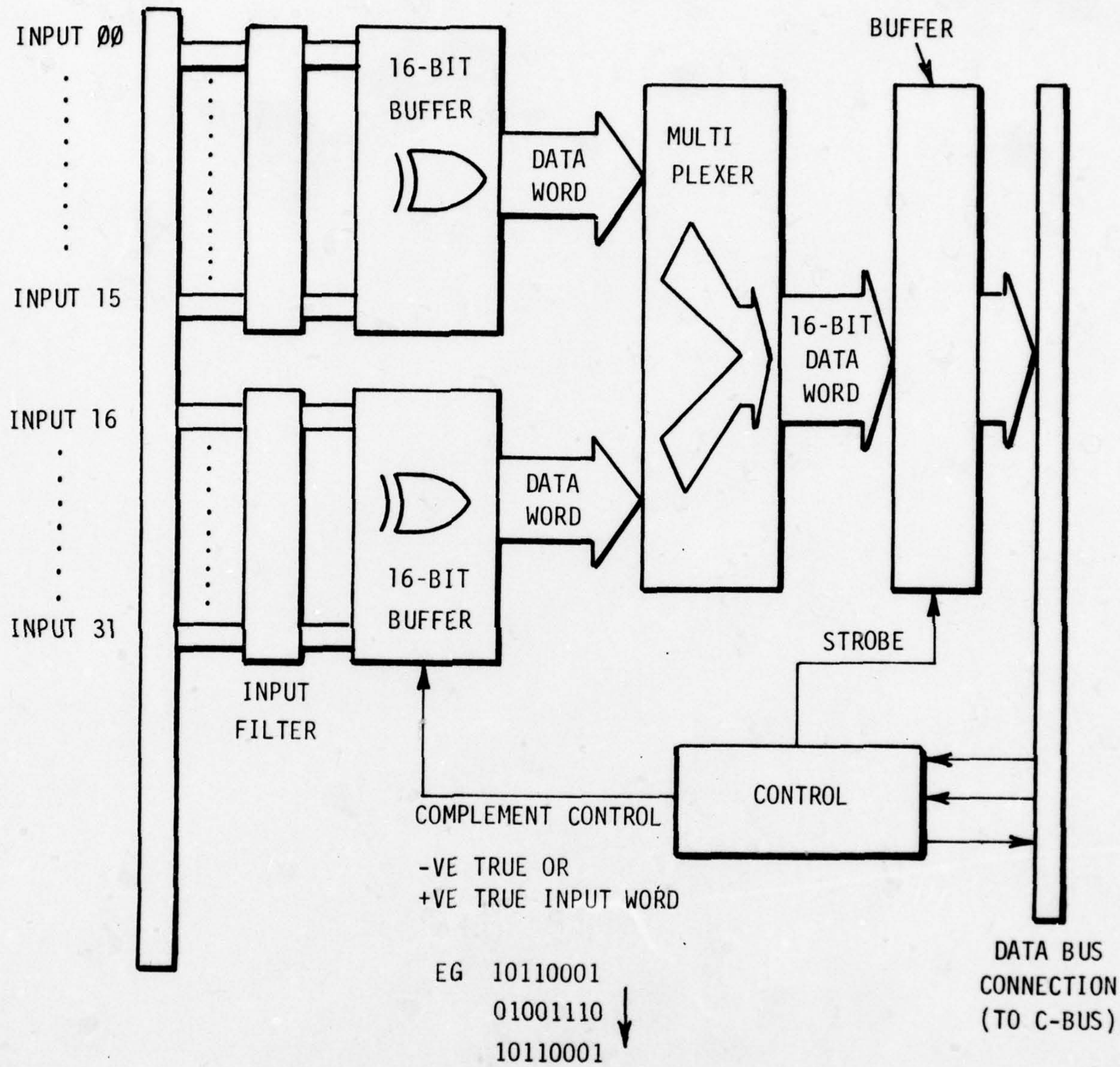



Figure F-14. Digital Input Card Block Diagram

# APPENDIX G

# AIRCRAFT EQUIPMENT LIST

## G.1 INTRODUCTION

The aircraft equipment list contained in this Appendix shows the AH-64 instruments and control panels resident in the AH-64 pilot's and CPG's cockpits. Against each item of equipment is an estimate of AH-64 FWS interface requirements between training area and digital computers. The mneumonics used are as follows:

- AIPS for reading dc voltage levels,
- SOPS for driving synchro type mechanisms,
- AOPS for dc voltage level outputs,
- DOPS for on/off output for lights and relays,
- DIPS for switching on/off input.

TABLE G-1. PROVISIONAL AH-64 INSTRUMENT AND DISPLAY LIST AND INTERFACE ASSIGNMENT

(SHT.1 of 4)

| NAME | QTY | INTERFACE ASSIGNMENT (3.3.6.2) AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| Airspeed Indicator | 2 | | 2 | | | |
| Clocks, 8-day mechanical | 2 | | | | | |
| Compass, standby magnetic | 1 PLT | | 2 | | | |
| Instantaneous Vertical Speed Indicators (IVSI) Pilot size 3", CPG size 2" | 2 | | 2 | | | |
| Radio Magnetic Indicator (RMI) showing gyromagnetic compass and ADF | 1 CPG | 5 | 4 | | 2 | 1 |
| Rate of turn indicator and slip ball | 1 PLT | | | 2 | | |
| Accelerometer<br>Main pointer for present accel + auxiliary pointers for man positive and negative accels. | 1 PLT | | 1 | | | |
| Altimeter, barometric | 2 | | 2 | | | |
| Horizontal Situation Indicator (HSI) Displaying | 1 PLT | | | | | |
| a) LDNS bearing to destination wrt helicopter heading | | | 1 | | | |
| b) LDNS distance to destination | | | 4 | | | |
| c) LDNS course deviation | | 1 | | | | |
| d) Helicopter heading - magnetic | | | 4 | | | |
| e) ADF bearing | | | 1 | | | |
| f) Selected course and heading | | 4 | | | | |
| g) Digital course readout | | Special Digital Board | | | | |
| h) Heading fail flag | | | | | 1 | |
| i) Navigation fail flag | | | | | 1 | |
| j) Distance invalid flag | | | | | 1 | |

(SHT.2 of 4)

| NAME | QTY | INTERFACE ASSIGNMENT (6.3.6.2) AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| Electronic Attitude Director Indicator (EADI)<br>electronic display unit and electronic unit to interface to multiplex data bus to MIL-STD-1553.<br>Display Information<br>1) Helicopter reference symbol<br>2) Attitude<br>3) Field Strength (FM homing)<br>4) Hover Steering (integrated doppler horizontal VH, VD velocity with compensations)<br>5) Radar altitude<br>6) TADS pointing angles<br>7) Speed (ground speed below 25 kts, airspeed above 25 kts)<br>8) FM homing steering<br>9) Cross track deviation<br>10) Time to go<br>11) Vertical velocity<br>12) Doppler Steering<br>Test display mode shall display all symbology | 1 PLT | | Special Interface to Multiplex Bus. | | | |
| EADI front panel with turn rate indicator, inclinometer, external controls (brightness, contrast, pitch trim, roll trim, and mode select) | 1 PLT | 3 | | | | 3 |
| Radar Altimeter AN/APR-209 | 2 | | | 4 | 10 | 10 |
| Attitude Indicator, standby | 1 PLT | | 2 | | | |

(SHT.3 of 4)

INTERFACE ASSIGNMENT (8.3.6.2)

| NAME | QTY | AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| Attitude Indicator, remote roll and pitch synchro inputs from Heading Attitude Reference Set (HARS) | 1 CPG | | 2 | | | |
| Turbine gas temperature, dual vertical scale and dual digital engines 1 and 2 | 1 PLT | | | 2 | | |
| Engine oil temperature, dual vertical engines 1 and 2 | 1 PLT | | | 2 | | |
| Engine torque, dual with a digital total - engines 1 and 2 | 2 | | | 4 | | |
| Triple tachometer, vertical | 2 | | | 4 | | |
| Gas Generator Speed (NL), dual vertical scale and dual digital | 1 | | | 2 | | |
| Engine oil pressure, dual vertical engines 1 and 2 | 1 | | | 2 | | |
| Fuel quantity, dual (FWD and AFT) with a digital total | | | | 2 | | |
| Selectable parameter digital display device | 1 CPG | | | | 24 | 6 |
| APU Gas gen Speed | 1 PLT OVHD | | | 1 | | |
| Hydraulic Pressure, dual (primary and utility) | 1 PLT | | | 2 | | |
| Emergency Hydraulic Control/ Display Panel | 1 PLT | | | | | |
| AC Loadmeter, dual | 1 PLT | | | 2 | | |
| DC Ammeter, dual | 1 PLT | | | 2 | | |

(SHT.4 of 4)

INTERFACE ASSIGNMENT (3.3.6.2)

| NAME | QTY | AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| Doppler Control Panel and Display Unit AN/ASN-128 | 1 CPG | | Special Interface | | | |
| Remote Doppler Control/Display Unit | 1 PLT | | Special Interface | | | |
| Outside Air Temperature | 1 PLT | | | 1 | | |
| Radar Warning Display AN/APR - 39 (V) 1 | 1 PLT | | Special Interface | | | |
| Pilots Integrated Helmet Display Sight System (IHADSS) | 1 | | Special Interface | | | |
| CPG Integrated Helmet Display Sight System | 1 | | Special Interface | | | |
| Gunners Video/Status Head-Up Display | 1 | | Special Interface | | | |
| Gunners Direct View/Video Head Down Display | 1 | | Special Interface | | | |

TABLE G-2. PROVISIONAL PILOTS PANELS AND CONTROLS LIST AND INTERFACE ASSIGNMENT (SHT.1 of 3)

| NAME | QTY | INTERFACE ASSIGNMENT (8.3.6.2) AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| Master Caution/Warning Panel | 1 | | | | 10 | |
| Integrated Fire Control Panel | 1 | 2 | | | 3 | 4 |
| Armament Control Panel | 1 | | | | | 8 |
| Selective Stores Jettison Control Panel | 1 | | | | | 4 |
| Intercommunications System Control Panel | 1 | | | 2 | 2 | 1 |
| Caution Panel | 1 | | | | 54 | |
| VHF-FM Radio Control Panel (AN/ARC-114) | 1 | | | 2 | 2 | 21 |
| Secure Voice Control Panel (TSEC/KY-28) | 1 | | | | | 4 |
| Hellfire Control Panel | 1 | | | | 7 | 4 |
| Automatic Stabilization Equipment (ASE) Control Panel | 1 | | | | 5 | |
| Rocket Control Panel | 1 | | | | 40 | 45 |
| Tail Wheel Lock Control Panel | 1 | | | | 1 | 1 |
| Electrical Power Control Panel | 1 | | | | | 6 |

(SHT.2 of 3)

INTERFACE ASSIGNMENT (8.3.6.2)

| NAME | QTY | AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| Engine Overspeed Test Control Panel | 1 | | | | | 5 |
| Fuel Control Panel | 1 | | | | 6 | 5 |
| Cabin Air Control Panel | 1 | 1 | | | | 2 |
| Anti-Ice Control Panel | 1 | | | | 3 | 9 |
| Lighting Control Panel | 1 | 5 | | | | 6 |
| Emergency dc Bus Circuit Breaker Panel | 1 | | No Data | | | |
| Collective Switch Panel | 1 | | | | | 12 |
| Radar Warning Control Panel | 1 | 1 | | | | 3 |
| UHF-AM Radio Control Panel (AN/ARC - 164) | 1 | | | 2 | 2 | 24 |
| VHF-AM Radio Control Panel (AN/ARC - 115) | 1 | 1 | | 2 | 2 | 20 |
| IFF Transponder Control Panel (AN/APX - 100) | 1 | | | | 4 | 40 |
| Automatic Direction Finder (ADF) Control Panel (AN/ARN - 89) | 1 | 4 | | 3 | 2 | 4 |
| Auxiliary Power Unit (APU) Control Panel | 1 | | | | 2 | 3 |
| Generator No. 1 Circuit Breaker Panel | 1 | | No Data | | | |
| Generator No. 2 Circuit Breaker Panel | 1 | | | | | |

(SHT.3 of 3)

| NAME | QTY | AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| | | INTERFACE ASSIGNMENT (8.3.6.2) | | | | |
| Compass System (HARS) Controller | 1 | 1 | | 1 | | 8 |
| Fire Extinguisher Bottle Select Switch | 1 | | | | | 2 |
| Engine Fire Handles | 2 | | | | 4 | 2 |
| Emergency Canopy Jettison Control Handle | 1 | | Not Required | | | |
| Conditioned Air Outlets | 2 | | Not Required | | | |
| Remote Transmitter Selector Display | 1 | | | | | 4 |
| Intercom Failure Override Control Switch | 1 | | | | | 2 |
| Parking Brake Lock/Release Handle | 1 | 1 | | | | |
| Directional Control Pedal Adjustment Control | 1 | | Not Required | | | |
| Power Lever Quadrant | 1 | 3 | | | 2 | 6 |
| Engine Power Chop Rotary Control | 1 | | | | | 1 |
| Collective Friction Adjustment Rotary Control | 1 | | Not Required | | | |

TABLE G-3. PROVISIONAL CO-PILOT/GUNNERS PANELS AND CONTROLS LIST AND INTERFACE ASSIGNMENT (SHT.1 of 2)

| | | INTERFACE ASSIGNMENT (3.3.6.2) | | | | |
|---|---|---|---|---|---|---|
| NAME | QTY | AIPS | SOPS | AOPS | DOPS | DIPS |
| Master Caution/Warning Panel | 1 | | | | 10 | |
| Armament Control Panel | 1 | | | | | 10 |
| Video Control Panel | 1 | 6 | | | | 6 |
| Status Display Control Panel | 1 | | | | | 4 |
| Fire Detector Test Control Panel | 1 | | | | 8 | 3 |
| Sight Select/Acquisition Source Select Panel | 1 | | | | | 17 |
| Hellfire Control Panel | 1 | | | | 12 | 30 |
| Data Control Panel | 1 | | | | | 10 |
| Data entry Keyboard | 1 | | | | | 6 |
| Caution Panel | 1 | | | | | 24 |
| Intercommunications System Control Panel | 1 | | | 2 | 2 | 1 |
| VHF-FM Radio Control Panel | 1 | | | 2 | 2 | 21 |
| TSEC/KY - 58 Secure Voice Control Panel | 1 | | | | | 4 |
| Emergency Fuel Control Panel | 1 | | | | | 6 |
| Interior Lighting Control Panel | 1 | 4 | | | | 1 |
| Anti-Ice Control Panel | 1 | | | | | 3 |
| Collective Switch Panel | 1 | | | | | 12 |
| Video Recorder Control Panel | 1 | | | | 12 | 7 |
| Fire Control Modes Control Panel | 1 | | | | | 14 |

(SHT.2 of 2)

| NAME | QTY | AIPS | SOPS | AOPS | DOPS | DIPS |
|---|---|---|---|---|---|---|
| | | | INTERFACE ASSIGNMENT (8.3.6.2) | | | |
| Circuit Breaker Panel | 1 | | | | | 29 |
| Fire Extinguisher Bottle Select Switch | 1 | | | | | 2 |
| Fire Control Handles | 2 | | | | 4 | 2 |
| Emergency Canopy Jettison Control Handle | 1 | | Not Required | | | |
| Conditioned Air Outlets | 2 | | Not Required | | | |
| Weapon Control Grip (Left Hand Operated) | 1 | 2 | | | | 9 |
| Sight Control Grip (Right Hand Operated) | 1 | 2 | | | | 12 |
| Pilot/Ground Override Switch | 1 | | | | | 1 |
| Portable Fire Extinguisher | 1 | | Not Required | | | |
| Directional Pedal Adjustment Control | 1 | | Not Required | | | |
| Power Lever Quadrant | 1 | 2 | | | | 4 |
| Intercom Failure Override Control Switch | 1 | | | | | 2 |
| Engine Power Chop Rotary Control | 1 | | | | | 1 |
| Collective Friction Adjustment Rotary Control | 1 | | Not Required | | | |

# APPENDIX H

## RELIABILITY AND MAINTAINABILITY ANALYSIS

## H-1 GENERAL

This appendix contains the AH-64 FWS Reliability and Maintainability Analysis for the computer interface, instructors stations, motion systems, visual systems, and flight compartments.

Each system and element which will affect the FWS training value is treated as a series chain, hence any failure causes total loss of the system. An ambient temperature of 35°C was assumed for the analysis. Failure rates were obtained from suppliers where available, MIL-HDBK-217B, NTIS Publication AD/A-005 657 (Nonelectronic Reliability Notebook), GIDEP Report #347-40-00-00-B8-05 (AVCO Reliability Analysis) and CAE field experience.

This analysis was based on a simulator constructed from commercial standard electrical parts and not military standard components and should be regarded as a conservative estimate. Figures for the Marconi Tepigen system are not yet available. The GE Compuscene system has been used as a basis for CGI system reliability estimates.

## H-2 SYSTEM FAILURE RATE ($\lambda$) AND MEAN TIME TO REPAIR (MTTR) SUMMARY

Table H-1 summarizes the overall Reliability, Maintainability and Availability data for two complete systems using the recommended and alternative visual systems.

## H-3 SYSTEM FAILURE RATE ($\lambda$) AND MEAN TIME TO REPAIR (MTTR) CALCULATIONS

Supporting data for Table H-1 covering the subsystems is given in Table H-2. Back-up sheets of the detailed calculations for each subsystem are available but are not included.

<u>Definitions</u>

| | | |
|---|---|---|
| $\lambda$ | = | Failure rate/$10^6$ hours |
| Mct | = | Minutes for each repair action |
| $\lambda$.Mct | = | Total repair minutes/$10^6$ hours |
| MTBF | = | Mean Time Between Failures (hours) |
| MTTR | = | Mean Time To Repair (minutes) |
| $\underline{A}$ | = | Availability (%) |

TABLE H-1. AH-64 FWS RELIABILITY AND MAINTAINABILITY SUMMARY

| SYSTEM | AH-64 FWS WITH 2 MODEL BRD/CCTV VISUALS & 1 TEPIGEN CGI VISUAL | AH-64 FWS WITH 3 TEPIGEN CGI VISUALS |
|---|---|---|
| $\lambda$ | 34,884.59 | 44,937.768 |
| MTBF | 28.67 | 22.25 |
| MTTR | 39.43 | 47.31 |
| $\underline{A}$ | 97.7 | 96.5 |

TABLE H-2 - SUPPORTING DATA

| SYSTEM | $\lambda$ | $\lambda$. Mct | $\Sigma\lambda$ | $\Sigma\lambda$. Mct |
|---|---|---|---|---|
| **Simulator Without Visual System** | | | | |
| Computer system and interface | 4,154.285 | 126,385.20 | | |
| Instructor's equipment | 1,537.076 | 42,426.43 | | |
| Motion systems | 2,000.0 | 114,900.00 | 19,252.128 | 584,861.89 |
| Flight compartment | 3,389.613 | 103,530.60 | | |
| Aircraft parts | 8,171.154 | 197,619.66 | | |
| **Recommended Visual System with 2 Model Board/CCTVs and 1 Tepigen** | | | | |
| 2 Model board/CCTV | 5,947.12 | 209,532.5 | | |
| 1 Marconi Tepigen | 8,000.00 | 480,000.0 | 15,632.76 | 790,688.94 |
| Display systems | 1,685.64 | 101,137.44 | | |
| **Alternative CGI Visual System** | | | | |
| 3 Tepigens | 24,000 | 1,440,000. | 25,685.64 | 1,541,137.4 |
| Display systems | 1,685.64 | 101,137.44 | | |
| **Recommended Complete Simulator** | | | | |
| Simulator without visual | 19,252.128 | 584,861.89 | 34,884.89 | 1,375,530.8 |
| Model Board/CCTV system plus Tepigen | 15,632.76 | 790,688.94 | | |
| **Alternative Configuration Using CGI Visual** | | | | |
| Simulator without visual | 19,252.128 | 584,861.89 | 44,937.8 | 2,125,999.3 |
| Model Board/CCTV system | 15,632.76 | 790,688.94 | | |

| ct | $\Sigma\lambda$ | $\Sigma\lambda$. Mct | MTBF | MTTR | A |
|---|---|---|---|---|---|
| 20<br>43<br>00<br>60<br>66 | 19,252.128 | 584,861.89 | 51.94 hours | 30.38 mins | 99% |
| 5<br>0<br>44 | 15,632.76 | 790,688.94 | 63.97 hours | 50.58 mins. | 98.7% |
| 44 | 25,685.64 | 1,541,137.4 | 38.93 hours | 60 mins. | 97.5% |
| 89<br>94 | 34,884.89 | 1,375,530.8 | 28.67 hours | 39.43 mins. | 97.7% |
| 89<br>94 | 44,937.8 | 2,125,999.3 | 22.3 hours | 47.31 mins. | 96.5% |

2

# APPENDIX I

## OFFICIAL VISITS AND CONFERENCES ATTENDED

## I.1 INTRODUCTION

The following is a list of places visited in connection with the AH-64 FWS study. These include military establishments, industrial suppliers, and international technical conferences.

[redacted]

Aberdeen Proving Ground, Maryland, USA.
U.S. Army Human Engineering Laboratory

Aviation Systems Command, St. Louis, Missouri, USA.

Concordia University, Montreal, Quebec, Canada
Symposium on 3-D Film and Television

Farrand Optical Co., Valhalla, New York, USA.

Fort Belvoir, Virginia, USA.
U.S. Army Night Vision Lab.

Fort Bragg, South Carolina, USA.

Fort Knox, Kentucky, USA.

Fort Monroe, Maryland, USA.

Fort Rucker, Alabama, USA.
U.S. Army Aviation Center
U.S. Army Aeromedical Research Lab.
U.S. Army Research Institute

General Electric, Syracuse, New York, USA.
Video Display Equipment

General Electric, Daytona, Florida, USA.

IFIP Congress-Exhibition, Toronto, Ontario, Canada

IMLAC., Needham, Massachusetts, USA.

Hughes Aircraft, Fullerton, California, USA.

John Piper Ltd., Kingston, Surrey, England

Luke AFB., Phoenix, Arizona, USA.

NASA - Langley, Hampton, Virginia, USA.

Naval Training Equipment Centre, Orlando, Florida, USA.

Naval Undersea Training Centre, San Diego, California, USA.

Northrop Corporation, Hawthorne, California, USA.
Aerosciences Lab.

Sanders Data Systems, Nashua, New Hampshire, USA.

Singer - Librascope, Glendale, California, USA.

Society for Information Display International Symposium, Boston, Massachusetts, USA.

Society of Photo-Optical Instrumentation Engineers International Technical Symposium, San Diego, California, USA.

Williams AFB., Phoenix, Arizona, USA.

Wright-Patterson AFB., Dayton, Ohio, USA.
AF/Human Resources Lab.
AF/Flight Dynamics Lab.

LIST OF ABBREVIATIONS

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AAH | Advanced Attack Helicopter |
| ACI | AC Input |
| ADC | Analog-to-Digital Conversion |
| ADF | Automatic Direction Finder |
| ADRS | Address Control Strobe |
| AF/HRL | Air Force/Human Resources Laboratory |
| AIP | Analog Input |
| AIR | Analog Reference Card |
| A/N | Alpha-Numeric |
| ANVIL | Alpha-Numeric Visual Instructors Layout |
| AOI | Area of Interest |
| AOP | Analog Output |
| APU | Auxiliary Power Unit |
| ARI | Army Research Institute |
| ARS | Aerial Rocket Subsystem |
| ASCII | American Standard Code II |
| ASE | Automatic Stabilization Equipment |
| ASH | Advanced Scout Helicopter |
| ASYNC | Address Sync |
| ATC | Air Traffic Control |
| AWS | Area Weapon Subsystem |
| | |
| BIC | Bus Interface Controller |
| BUCS | Backup Control System |
| | |
| CCD | Charge Coupled Device |
| CCTV | Closed Circuit Television |
| CDU | Computer Display Unit |
| CGI | Computer Generated Image |
| CHIFC | Chassis Interface Controller |

[redacted]

| | |
|---|---|
| CID | Classical Infinity Display |
| CIU | Computer Interface Unit |
| CPG | Copilot/Gunner |
| CPU | Central Processing Unit |
| CRT | Cathode Ray Tube |
| DA | Data Available |
| DACBUS | Data Acquisition and Control Bus |
| DEC | Digital Equipment Corporation |
| DGN | Diagnostic |
| DIP | Digital Input |
| DMA | Direct Memory Access |
| DNS | Doppler Navigation System |
| DOP | Digital Output |
| DOR | Data Output Relay |
| DR | Data Request |
| DVO | Direct View Optics |
| EADI | Electronic Attitude Display Indicator |
| FARRP | Forward Area Refueling and Rearming Point |
| FCC | Fire Control Computer |
| FHD | Fixed Head Disc |
| FLIR | Forward Looking Infrared |
| FOV | Field of View |
| FS | Field Sequential |
| FWS | Flight and Weapons Simulator |
| GCA | Ground Controlled Approach |
| GCU | Generator Control Unit |
| GE | General Electric Company |
| HARS | Heading Attitude Reference Set |
| HEAT | High Explosive Antitank |

| | |
|---|---|
| HEL | Human Engineering Laboratory |
| HELCAT | Human Engineering Laboratory Camouflage Applications Test |
| HELHAT | Human Engineering Laboratory Helicopter Applications Test |
| HMD | Helmet-Mounted Display |
| HME | Hellfire Missile Equipment |
| HMS | Helmet-Mounted Sight |
| HSFP | High-Speed Floating Point |
| HSI | Horizontal Situation Indicator |
| IFR | Instrument Flight Rules |
| IHADSS | Integrated Helmet and Display Sight System |
| ILS | Integrated Logistics Support/Instrument Landing System |
| I/O | Input/Output |
| IOB | Input Output Buffer |
| I/OP | Instructor/Operator |
| IPL | Initial Program Load |
| IR | Infrared |
| ISA | Instrument Society of America |
| IVSI | Instantaneous Vertical Speed Indicator |
| LED | Light Emitting Diode |
| LDNS | Lightweight Doppler Navigation System |
| LOS | Line of Sight |
| LRF/D/T | Laser Rangefinder/Designator/Tracker |
| LRU | Line Replaceable Unit |
| LU | Logic Unit |
| LVDT | Linear Variable Differential Transducer |
| MAITAC | Map Interpretation and Terrain Analysis Course |
| MHD | Moving Head Disc |
| MOS | Metal Oxide Semiconductor |
| MTF | Modulation Transfer Function |
| MTT | Magnetic Tape Transport |
| MTBF | Mean Time Between Failures |
| MTTR | Mean Time To Repair |

| | |
|---|---|
| NASA | National Aeronautics and Space Administration |
| NDB | Non-Directional Beacon |
| NOE | Nap of the Earth |
| NTEC | Naval Training Equipment Center |
| NTSC | National Television Standards Committee |
| NVL | Night Vision Laboratory |
| OS | Operating System |
| PLZT | Lead Lanthanate Zirconium Titante |
| PM TADS | Project Management, Target Acquisition Designation System |
| PM TRADE | Project Management, Training Devices |
| PNVS | Pilot Night Vision System |
| PRF | Pulse Repetition Frequency |
| PTIT | Power Turbine Inlet Temperature |
| PTS | Point Target Subsystem |
| RAM | Random Access Memory |
| RF | Radio Frequency |
| RMI | Radio Magnetic Indicator |
| RT | Remote Terminal |
| RVR | Analog Control Voltage |
| RWS | Radar Warning System |
| SDC | Shaft Driven Compressor |
| SEL | System Engineering Laboratories |
| SID | Society for Information Display |
| SIMTOS | Simulator Iterating Multi Tasking Operating System |
| SIP | Synchro Input |
| SRL | Systems Research Laboratories, Dayton, Ohio |
| SOP | Synchro Output |

| | |
|---|---|
| TADS | Target Acquisition Designation System |
| TEPIGEN | Television Picture Generator |
| UTM | Universal Transverse Mercator |
| VFR | Visual Flight Rules |